Evidential basis for community response to land transport noise

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An important note for the reader

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Abbreviations and acronyms

%HA	percentage highly annoyed
AADT	annual average daily traffic
CATI	computer assisted telephone interviewing
CBD	central business district
CNEL	community noise equivalent level
CRN	calculation of rail noise
CRTN	calculation of road traffic noise
dB	decibels
DNL	day/night level
EU	European Union
I-INCE	International Institute of Noise Control Engineering
ISO	International Organization for Standardization
$L_{Aeq(time)}$	A-weighted continuous equivalent sound level over stated time period (in this report typically 24 hours)
L_{A10}	sound level which is equalled or exceed for 10% of the measurement time
L_{den}	day/evening/night level - L_{Aeq} over a 24-hour period with the addition of 10 decibels to sound levels at night (11pm–7am) and 5 decibels to sound levels in the evening (7pm–11pm)
L_{dn}	(DNL) day/night level - L_{Aeq} over a 24-hour period with the addition of 10 decibels to sound levels at night (10pm–7am)
NZ	New Zealand
NZS	New Zealand Standard
RAMM	Road Asset and Maintenance Management
RoNS	Roads of National Significance
SH	State Highway
WHO	World Health Organisation

Contents

Executive summary **7**
Abstract **10**
1 Introduction **11**
1.1 Background 11
1.2 Objectives of the research 11
2 Literature review **13**
2.1 Research methodologies and questionnaire development 13
2.2 Noise exposure results 20
2.3 Geographical and social effects 25
2.4 Health effects of noise exposure 32
2.5 Summary 33
2.5.1 Suitable criteria 33
2.5.2 Measurement and modelling 33
2.5.3 Interview design 33
2.5.4 Sample selection 34
3 Study area selection **36**
3.1 Survey areas 36
3.1.1 RoNS overview 39
3.1.2 Christchurch – Northern Arterial 42
3.1.3 Auckland – Waterview Connection 43
3.1.4 Waikato Expressway 44
3.1.5 Wellington Northern Corridor – Mackays to Peka Peka 46
3.1.6 Site selection 46
3.1.7 Study areas 47
3.2 Noise levels 47
4 Survey design **49**
4.1 Sample selection 49
4.2 Survey development 49
4.3 Interviewing process 50
4.4 Quality assurance processes and standards 52
5 Data analysis **54**
5.1 Demographics 54
5.1.1 Representation 57
5.2 Confidence intervals 58
5.3 Noise annoyance dataset 58
5.3.1 Reported annoyance 59
5.3.2 Percentage highly annoyed 61
5.3.3 Time of day effects 68
5.4 Survey comments 68
5.4.1 Summary 71
6 Conclusions and recommendations **72**
6.1 Conclusions 72

6.2 Recommendations 73
7 References **74**
Appendix A: Site selection **78**
Appendix B: Study questionnaire **104**
Appendix C: Pre-notification letters **112**

Executive summary

Noise annoyance

Road traffic noise and rail noise is recognised as the main source of land based environmental noise pollution and the World Health Organisation indicates that within Europe more than half of its inhabitants are exposed to noise levels considered to be detrimental to acoustics comfort. The threshold at which individuals will be annoyed by road and rail noise will vary depending upon the expectations of the respondent and their sensitivity to noise. Noise effects can range from general annoyance and disturbance to short-term and long-term health effects.

Scope of study

The NZ Transport Agency (the Transport Agency) aims to be a good neighbour, taking social and environmental responsibility seriously and in 2015, a research study was commissioned by the Transport Agency to assess community response to sources of road and rail noise. The objective of the research was to undertake a New Zealand community response study to determine the noise dose-response relationship based on a comparison of short-term changes in noise compared with existing steady-state conditions.

Due to a number of limitations this objective could not be fulfilled and the research study design was adapted. The findings of the study were compared against similar studies undertaken internationally, specifically studies that had meta-analysed data from a number of multiple studies.

Literature review

To assist with the design of the study a review of the literature was undertaken to establish the current state of thinking when developing research studies and their questionnaires. The literature review also investigated the influence of geographical and social effects relating to community attitudes to land-based transportation noise and the health effects associated with environmental noise.

Study design

The practicalities of conducting a community response study were considered and a combination of telephone and online questionnaires were used to seek individual opinions regarding noise from different sources, as well as demographic information. Three study areas were chosen within Auckland from a shortlist of sites across the county:

- existing road (steady-state conditions) – Auckland State Highway 1 (‘SH 1’)
- new or altered road (short–term noise change) – Auckland SH 20 Waterview Connection (‘Waterview’)
- rail (steady-state conditions) – Auckland southern rail corridor (‘rail’)

Limited new or altered road projects within New Zealand restricted the selection of suitable survey areas to those that not only met the requirement of having sufficient population with a range of noise exposures but also allowed a change in noise exposure to be surveyed both before and after the opening of the project or after a change in traffic conditions. Although the Waterview Connection project was opened in July 2017, at the date of the survey the project was still under construction and therefore the survey results are representative of the steady-state conditions prior to the introduction of the new road traffic. As there are no major rail projects across New Zealand, the rail study area was restricted to the existing rail traffic movements of the Auckland southern rail corridor.

Within each study area, calculations of road and rail noise levels greater than a 24-hour $L_{Aeq(24h)}$ of 45 dB were determined using standardised procedures based on New Zealand conditions. For each study area, a percentage highly annoyed (%HA) analysis was undertaken and the findings compared including comparison with meta-analysis data obtained from the literature review.

Main study findings

Despite choosing Auckland for its population density, difficulty was still encountered when trying to achieve the target number of completed interviews within the relatively small population sizes of the Waterview Connection and rail study areas. Initially telephone interviews were conducted which were then supplemented with online questionnaires to increase the response rate.

The results based on the total study sample of n=801 respondents are subject to a maximum margin of error of ±3.5 % at the 95th percentage confidence level. This means, for example, that if 50% of respondents reported being affected by road traffic noise, there would be a 95% confidence of getting the same result, plus or minus 3.5%, had all eligible households been interviewed within the three study areas. To enhance data collection for similar projects a number of suggested improvements have been made.

Not surprisingly there is a heavy reliance on car usage across all study areas. Out of a list of 10 sources of environmental noise, road traffic was rated most annoying, and for the rail study area, train noise was rated fifth most annoying noise source.

In comparison to the other study areas, SH 1 on average achieved a lower occurrence of high annoyance. Excluding road traffic, the aggregate annoyance score for SH 1 was calculated to be 5%, whereas the other two study areas have an average high annoyance score of 15%.

When comparing the onset of significant community response (scores of 20 %HA or more) for each study area and noise source, the rail study area has the highest onset at 62dB $L_{Aeq(24h)}$ compared with 59 and 58 dB $L_{Aeq(24h)}$ for SH 1 and Waterview respectively. These findings agree with those of Miedema and Vos (1998) who observed that rail noise was less annoying than road traffic noise for the same noise level. The analysis suggests the New Zealand population is more sensitive to noise, as the onset of significant community response occurs at lower sound levels, approximately 13 dB lower for rail and 6 dB lower for road, when compared with Miedema and Vos.

Respondents were asked to provide general feedback on noise and other matters. It was noted that the impact on lifestyle was a concern, which included general disturbance and interference with their quality of life. Interestingly driver behaviour accounted for the greatest number of comments with ‘boy racers’ and ‘trucks’ being cited as the two most common sources of noisy events.

Although the questionnaire did not enquire how a respondent’s annoyance varied with time of day and day of the week, there is evidence to show that respondents were more annoyed at different times of the day and night. For future studies the inclusion of a ‘time of day’ annoyance question is recommended to determine whether there is a greater likelihood of more people being highly annoyed during the evening and night periods and therefore supporting the use of separate noise metrics or noise metric weighting factor(s) for these time periods. Care may be needed to ensure the overall duration of the study remains acceptable.

Although the principal objective of the study, which was to compare community response to short-term changes in noise compared with existing steady-state conditions, was not fulfilled, it is recommended that future studies should aggregate the results from a number of sites to increase the population size and hence statistical confidence in the results.

In the short term, an assessment of the following four Roads of National Significance is recommended:

- Auckland Western Ring Route
- Waikato Expressway – SH 1
- Wellington Northern Corridor
- Christchurch Motorways.

Abstract

Environmental noise caused by road and rail traffic can cause a range of disturbance and annoyance reactions amongst local communities. The threshold at which individuals will be annoyed by these sources of noise will vary depending on the expectations of the respondent and their sensitivity to noise. A community noise annoyance study was performed in Auckland, New Zealand to determine the noise dose-response relationship based on a comparison of short-term changes in noise compared with existing steady-state conditions. Due to limitations, a revised study design was implemented and three study areas were selected: 1) subject to transportation noise from an existing state highway, 2) a newly constructed but un-opened road, and 3) an existing rail line. A social survey of community response was undertaken within the three study areas. A percentage highly annoyed (%HA) analysis was undertaken for each study area and the findings compared with meta-analysis data obtained from a comprehensive literature review. Out of a list of 10 sources of environmental noise, road traffic was rated most annoying and for the rail study area, trains were rated fifth most annoying noise source. The %HA analysis compared well with other studies, although in each case the onset of annoyance occurred at a marginally lower sound level. Further work is recommended to establish the relationship between short-term changes in noise compared with existing steady-state conditions.

1 Introduction

1.1 Background

The World Health Organisation (WHO) (Berglund et al 1999) acknowledges that excessive noise can harm human health and interfere with people's daily activities at home, at cardiovascular school, at work and during leisure time. High levels of noise can disturb sleep, cause and psychophysiological effects, reduce performance and provoke annoyance responses and changes in social behaviour.

Community noise (also called environmental noise) includes noise from all sources except noise within the workplace. Sources of community noise include road, rail and air traffic, construction sites, industrial and commercial premises and general neighbourhood noise. Transportation noise is recognised as the main source of environmental noise pollution and WHO statistics indicate that within Europe more than half of its inhabitants are exposed to noise levels considered to be detrimental to acoustics comfort (World Health Organisation nd).

Noise nuisance surveys have shown that on a per-person basis, a community's sensitivity to transportation noise varies considerably, and that the response differs depending upon the source, and that attitudes to noise are also related to satisfaction with their neighbourhood in general. This variability in individual responses has led to the concept of an average or community annoyance rating for each decibel level of transportation noise, ie a noise dose and response relationship.

Most dose-response surveys have compared noise and nuisance levels where steady-state conditions prevail (no sudden change in exposure to transportation noise). When there is a change following the opening of a road for example, Schomer (2005) suggests people are more sensitive to short-term changes in noise exposure. People may be sensitised because of publicity surrounding the project and the expectations associated with a forthcoming change. They may be more influenced by non-acoustic factors, such as visual intrusion, and social, economic or other differences. Over time, this sensitivity has been shown to reduce (Schomer 2005).

The NZ Transport Agency (the Transport Agency) aims to be a good neighbour, taking social and environmental responsibility seriously. To assist with this commitment, AECOM New Zealand Limited (AECOM) was contracted by the Transport Agency to carry out a dose-response survey to assess people's attitudes to sources of land-based transportation noise with an aim being to determine whether there is a difference in community response following the opening of a new road. Due to limitations in the suitability and availability of 'before and after' projects, the scope of the research was varied to assess pre-existing conditions with a view to undertaking future work once the selected road was open and traffic conditions had stabilised. AECOM was supported by Research New Zealand who assisted in the sampling methods, conducted the interviews and assisted in the data interpretation.

1.2 Objectives of the research

The New Zealand road traffic noise standard (New Zealand Standard NZS 6806:2010) recommends noise criteria to determine the adverse effects of road traffic noise on people. The standard also establishes procedures for the prediction, measurement and assessment of road traffic noise. The standard aids in the design of new and altered roads by setting reasonable criteria which take into account health issues associated with noise, the effects of relative changes in noise levels of people and communities, and the potential benefits of new and altered roads to people and communities.

The standard assesses the change in noise at a point in the future some 10–20 years after the opening of the roading scheme (design year); it does not assess the short-term changes in people's attitudes to noise, ie immediately following the opening of a scheme. Concern has been expressed (NZ Transport Agency 2011) that NZS 6806:2010 may not fully reflect the effects of road traffic noise on people. The outcomes of this study may assist future Transport Agency decisions on road traffic noise and may also be used to inform any future updates to NZS 6806:2010. In New Zealand there are no standards for rail noise.

The objective of this research was to undertake a New Zealand community response study to determine a noise dose-response relationship based on a comparison of short-term changes in noise with existing steady-state conditions. In doing so, the study aimed to establish:

- the current state of thinking for community response surveys by means of a literature review
- a noise dose-response relationship for three study areas (existing road, new or altered road and new or altered rail)
- the difference between existing and new exposure to road (and rail) noise, ie short-term effects.

Due to limitations in the suitability and availability of 'before and after' projects, the objective to assess short-term effects was not achieved in full. The scope of the research was amended with a view to undertaking future work once the selected road was open and traffic conditions had stabilised. These limitations are discussed further in this research report.

2 Literature review

There is a large body of evidence which confirms environmental noise, and in particular transportation noise, causes disturbance and depending upon the level of exposure, can have an adverse effect on health. The main findings of the research are summarised in this chapter. It should be recognised that the total literature on this subject is vast and ever increasing, and the review can therefore be considered a small but focused snapshot across a range of opinions and findings.

The literature review does not reflect the most recent work on this subject matter as it was undertaken in 2015/2016. However, the WHO's (2018) noise guidelines build upon some of the literature presented below, and while there are no new findings, the 2018 guidelines do provide specific recommendations for land-based transportation noise. These recommendations include reducing exposure to noise and promoting interventions to reduce exposure to noise and improve health.

To assist with the design of this project, differing experimental methodologies for evaluating community noise annoyance are discussed.

2.1 Research methodologies and questionnaire development

Fundamental to the development of an effective social survey is considering the standard methods that have been used by previous researchers. ISO/TS 15666 (ISO 2013) represents a means of standardising socio-acoustic surveys between researchers and this technical specification was used to guide the development of the survey questionnaire used in this project. It is recognised that the ISO is just one method of data collection and alternative survey approaches have been used by other researchers.

The technical specification of the ISO is limited to obtaining information about the noise annoyance 'at home' and focuses on ensuring the data collected in a survey achieves a high level of comparability with other studies.

ISO/TS 15666 presents two formats for eliciting a measurable response in socio-acoustic surveys: a verbal rating scale and a numerical rating scale. For measuring noise annoyance, it suggests using a negative-neutral scale where the range of the scale goes from a neutral response to a totally negative response. A verbal rating scale uses a selection of possible responses to measure a participant's annoyance, for example:

> *Thinking about the last (12 months or so), when you are here at home, how much does noise from (noise source) bother disturb or annoy you?*
>
> *Not at all?*
>
> *Slightly?*
>
> *Moderately?*
>
> *Very?*
>
> *Extremely?*

In comparison, a numerical rating scale allows a participant to place their annoyance as a number between two extremes, for example:

This uses a 0 to 10 opinion scale for how much (source) noise bothers, disturbs or annoys you when you are here at home. If you are not at all annoyed choose 0; if you are extremely annoyed choose 10; if you are somewhere in between, choose a number between 0 and 10.

Thinking about the last (12 months or so), what number from 0 to 10 best shows how much you are bothered, disturbed of annoyed by (source) noise?

The technical specification also details a number of rules that should be followed to reduce bias due to the question and interview structure. These rules are relatively limited in scope and will be explored further in the following paragraphs. Finally, table 2.1 presents the minimum specifications required to ensure adequate core information is reported in surveys. A technical report would also require a discussion and evaluation of the survey results.

Table 2.1 Minimum specifications for reporting core information from social and socio-acoustical surveys in scientific reports

Topic area	Item	Topic	Required information
Overall design	1	Survey date	Year and months of social surveys
	2	Site location	Country and city of study sites
	3	Size selection	Any important, unusual characteristic of the study period or sites Map or description of study site locations relative to the noise source
	4	Site size	Rational for site selection Site selection and exclusion criteria
	5	Study purpose	Number of study sites Number of respondents by site State original study goals
Social survey sample	6	Sample selection	Respondent sample selection method (probability, judgemental, etc) Respondent exclusion criteria (age, gender, length of residence, etc)
	7	Sample size and quality	Response rate Reasons for non-response
Social survey data collection	8	Survey methods	Method (face-to-face, telephone, etc)
	9	Questionnaire wording	Exact wording by primary questionnaire items (including answer alternatives)
	10	Precision of sample estimate	Number of responses for main analysis
Acoustics conditions	11	Noise source	Type of primary noise source (aircraft, road traffic, etc) Types of noise source operations that are included or excluded Protocols to define the noise source (eg minimum level, operations, days of week)
	12	Noise metrics	Give the complete description of any noise metric reported, according to ISO 1996-1, ISO 1996-2, ISO 1996-3 or ISO 3891 (if applicable) • Provide $L_{Aeq(24hr}$, L_{dn} and L_{den} (or L_{Aeq} by time-period) for all locations or • Provide conversion rule(s) to estimate $L_{Aeq(24hr)}$, L_{dn} and L_{den} under the specific study conditions from the study's preferred metric • Discuss the adequacy of the conversion rule(s) • Provide impulse and/or tone corrections

Topic area	Item	Topic	Required information
	13	Time period	Hours of day represented by noise metric Period (months, years) represented by noise metric
	14	Estimation/ measurement procedure	Estimation approach (modelling, measurement during sampled period, etc)
	15	Reference position	Nominal position relative to noise source and reflecting surfaces Present exposure (or give conversion rule) for noisiest façade, specifying whether reflections from the façade are taken into account or not
	16	Precision of noise estimate	Best information available on precision of noise exposure estimates
Basic dose/ response analysis	17	Dose/ response relationships	Tabulation of frequency of annoyance ratings for each category of noise exposure

Source: ISO 15666 (2013)

A number of methodologies can be used to perform social surveys. Corbetta (2003) presented an in-depth review of methods for undertaking social surveys. The questionnaire used in a survey will influence the overall results, therefore developing a suitable and effective questionnaire is imperative. Corbetta presents a list of 21 factors that should be considered in developing a questionnaire; these factors align closely to those presented in ISO 15666 but are more general in their application. These factors are presented in a condensed manner below:

- **Simplicity of language and syntax**. It is important that any questions asked be accessible for all respondents. In the setting of a socio-acoustic study care must be taken to ensure that technical terminology is avoided. The use of complex syntax, such as double negatives, can further confuse respondents.
- **Question length and survey length**. The questions asked must be sufficiently short to ensure the respondent does not lose the meaning of the question, ie questions should be concise, clear and simple. These rules also apply to the overall questionnaire as respondents may lose interest or become bored if lengthy.
- **Number of response alternatives**. The number of response alternatives should be limited to a manageable number so that the respondent does not become confused. This is especially important in read interviews (eg telephone interviews).
- **Use of slang, ambiguous or vague definitions, abstract questions and answers**. Terms which are not clear or use slang may confuse or alienate respondents. The use of clear terms also aids in developing a concise questionnaire. Abstract questions or questions that require abstract answers should be avoided as they can confuse or frustrate respondents.
- **Emotive terms or loaded questions**. The use of highly emotive terms may cause the respondent to answer in a non-objective way. Loading of a question may prime a respondent to answer in a positive or negative manner. Care should be taken to avoid influencing the respondent's answer via the wording of the question.
- **Non-discriminating questions or questions with unequivocal answers**. Non-discriminating questions do not yield variations between respondents (for example a question where all respondents will answer yes) do not offer added information and increase the length of the survey. Questions

without a clear answer or questions with multiple answers for the same respondent cause confusion for the respondent.

- **Presumed behaviour**. Survey questions should not assume that the respondent acts or behaves in a certain way.
- **Memory effects**. In general questions that require a respondent to remember a single event will encounter difficulties. Instead, asking a question about a timeframe is generally simpler for respondents to understand.
- **Question order**. The order of questioning can significantly impact the results of a survey. In structuring a survey several factors need to be considered; the respondent must be eased into any difficult or complex questions, the respondent's interest and tiredness should influence the location of questions, and the questioning should follow a logical sequence. Due to these factors it is generally best to locate questions that require significant thought in the middle of the survey, and it is essential to ensure that the questioning avoids sudden changes in type or context.

The method by which the survey is administered influences the results, scale, and cost of the survey. Table 2.2 summarises four of the major survey types. Each survey type has clear strengths and weaknesses; the primary balance is between cost and time, and the quality of the data collected.

Table 2.2 Comparison of different survey interview types

Topic	Face to face	Telephone	Mail/self-completion	Web
Sample	Postcode address	Random digit	Postcode address	
Sample type	Probability	Probability	Probability	Non probability
Turnaround time	Slow	Fast	Fast	Fast
Cost	High	Medium	Low	Very Low
Interviewers required	Yes	Yes	No	No
Interview length	Up to 2 hours	Maximum ½ hour	Maximum 15 minutes	Maximum 15 minutes
Response rates	High	Medium	Low	Low
Main advantages	High response rates Better quality of data More complex questions Longer time to interview hence more data collected Interviewer rapport with the respondent	Low cost Able to reach a large number of geographically spread population Fast turnaround time	Low cost Able to reach a large number of geographically spread population	Low cost Able to reach a large number of geographically spread population Able to use visual aids in web surveys
Main disadvantages	High set up costs Interviewers need training and supervision Long time in the field	Low response rate Sampling problems with key groups Unable to ask long or complex questions or use visual aids	Low response rate Poor quality data if respondents misunderstand the questions No control over resident selection	Sampling issues Poor quality of data Low response rates

Source: Corbetta (2003)

Phone interviews effectively balance these two factors, although it must be noted they have some disadvantages:

- Some key groups may be hard to effectively sample, especially with the increasing number of people who only use mobile phones[1].
- The interviewers are unable to ask complex questions or use visual aids.
- People are less inclined to answer personal questions over the phone.
- Response categories and overall survey must be relatively short.

Response rates will also vary according to the available population sample and for some studies a variety of techniques may be required. Nevertheless, low response rates will increase the confidence intervals and care should be taken when reaching conclusions.

The International Institute of Noise Control Engineering (I-INCE) produced a set of guidelines for assessing and mitigating community noise (TSG6 2011). This report was intended to provide practical guidance to policy makers and includes an assessment of environmental impact analysis, dose-response relationships and land use planning. 'Appendix A: State-of-knowledge concerning the effects of community noise' was of special interest for this literature review as it identifies a general process that has been followed by the majority of researchers performing socio-acoustic surveys in the past 50 years. The process is as follows:

1 Identify the effect of interest, for example: community annoyance, sleep disturbance, cardiovascular effects.
2 Design and conduct an experiment. Generally statistical surveys or laboratory experiments.
3 Analyse the results and compare with other similar research results. Comparing with existing results allows the data to be validated and the results to be discussed in context.

There is a large variation in the level of understanding and knowledge about exposure response curves for different noise effects including annoyance, sleep disturbance, sleep structure and others. The most sophisticated dose-response curves exist for community annoyance, as this has received significant research. The I-INCE appendix identifies a computational lower cut-off level of 40–45 dBL_{dn} or L_{den} where community noise becomes measurable and a level of 55 dB where the potential for significant annoyance begins.

There are significant uncertainties in performing socio-acoustic surveys, and these are discussed in the I-INCE article. It is expected there will be inherent variability in community responses due to either measurement difficulties or inevitable differences in human responses. The first can be managed using good experimental design and implementation, whereas the latter will be present in all surveys. Major sources of variability and uncertainty are:

- Predicting actual noise exposures of participants. This is due to difficulties in assessing the amount of time and the location of people within their homes, and the obvious impact this has on their individual noise exposures.
- Impact on people who work away from home. These people are not exposed to the actual noise levels present at their residence during most of the day.
- Differences in auditory performance of humans. This variation is well known and understood, but it will impose a limitation on how far variability in the results can be reduced.

[1] Mobile phones may not be registered at the address where the intended respondent resides

- Other factors, due to aspects such as noise tolerance, geographical, cultural and socio-economics, will also cause variability in the results. These factors are discussed more fully later in this literature review.

The specific wording of a survey can significantly alter the results; this is especially true when any form of annoyance is being evaluated. Rohrmann (1998) published a study that focused on the influence verbal labels have on noise annoyance scales. The relative strengths of a range of responses were evaluated using psychometric tests. A summary of the strength of different responses in relation to noise annoyance is given in table 2.3.

Table 2.3 Scaling of verbal qualifiers for noise annoyance

Verbal label	Strength of response (0 to 10 scale)	Verbal label	Strength of response (0 to 10 scale)
A little	2.5	Moderately	4.9
Average	4.7	Not	0.4
Completely	9.8	Not at all	0.1
Considerably	7.5	Partly	3.5
Extremely	9.6	Quite	6.1
Fairly	5.1	Quite a bit	6.4
Fully	9.2	Rather	5.9
Hardly	1.6	Slightly	2.5
Highly	8.6	Somewhat	4.3
Mainly	6.4	Very	8.0
Medium	4.8	Very Much	8.7

Source: Rohrmann (1998)

It must be stressed that these values were performed for Australian English and cannot be directly generalised for English, New Zealand English, or American English. It is also important to note that these conclusions do not apply to any other languages. These relative levels should be used to guide the selection of a suitable set of verbal identifiers. ISO/TS 15666 (2003) was produced to overcome some of these verbal label misunderstandings; this is discussed later in this chapter.

The results of a European Cooperation in Science and Technology (COST) action working group study presented the development of a socio-acoustic survey for noise properties of residential buildings (Simmons 2013). While this document specifically applies to noise in buildings the development of the socio-acoustic survey remains relevant. An important consideration is to ensure that the question is direct and clear as this reduces variations in responses. The variation between different words and how they are interpreted means that verbal scales are prone to bias type errors, such as the perceived differences in scale between pairs of words, for example ‘moderately’ and ‘very’ are perceived to be further apart than ‘not-at-all’ and ‘slightly’. These scaling issues caused the COST action group to resort to an 11 point (0–10) numerical scale, with only the extremes defined. It should be noted that ISO 15666 suggests the questionnaire should repeat questions with a numerical scale and a set of verbal identifiers.

Statistics NZ (2014) *A guide to good survey design* provides information for organisational planning and undertaking social surveys. The guide identifies issues associated with planning, undertaking, commissioning, managing and processing a survey. An overview of the pertinent issues raised is presented here (see Statistics NZ 2014 for further information). The main sections of the guide focus on:

- preparation for undertaking a survey
- survey management
- sample selection
- questionnaire development
- sources of error
- processing and presentation of survey results.

The section on preparation presents a series of questions that are useful in defining the scope and scale of the survey. Initial planning should focus on identifying available timeframes and finances, and establishing relationships necessary for undertaking the survey. It is also important to ensure the survey objectives are adequately defined, and to accurately define the end user of the survey data to ensure the end results are as expected.

To effectively manage a survey it is important that all the steps of the survey are well defined and that a plan is developed to manage each phase of the survey. Typical surveys require management of the following phases:

- Planning: approvals for funding, engaging sub-contractors, preparation of detailed timetables, approval of survey design, consultation with end users and advisors.
- Consultation with end users, sponsors, contractors, designers.
- Design: identify and fill key roles, identify required classifications and definitions, evaluate existing classifications and standards.
- Pre-tests and pilot surveys: identify how and when these will be undertaken.
- Operation: identify how data will be collected, who will collect the data, how are interviewers matched to respondents, and what quality assurance will be implemented.
- Non-response: identify what approach will be used in the case of non-responses and partial responses, and how this data will be incorporated.
- Processing and analysis: identify the required data processing expertise, ensure necessary software is available, develop metrics for results and accuracy checking.
- Reporting: develop templates for reporting data, how will privacy and confidentiality be handled, where will the results be realised.
- Major problems: develop a plan for major issues that may arise during the survey, such as low response rates, inaccurate data, insufficient time or resources.

The selection of a suitable sample population is fundamental to the accuracy of the survey results. First target populations need to be identified; in this survey this is residents who live in an area affected by road traffic noise from new and existing roads and railways. It is not practical to survey all residents in New Zealand who fall within this category; as such it is necessary to identify a suitable subgroup to be surveyed. This survey population should accurately represent the overall target population. A method for randomising the survey population is also required to ensure no biases are present in the selection process.

An often overlooked, but vital component of survey design is the development and testing of a questionnaire. Poor questionnaires can lead to increased non-sampling error, increased non-response or partial response, and increased analysis costs. The questionnaire needs to be tested and refined using peer review and user testing. Statistics NZ (2014) identifies a list of pitfalls in section 6.6 that are important to consider.

The analysis and presentation of the results is the final stage of the survey and warrants significant investment. The manner in which the results are analysed and presented is the main way the end user will interact with the survey results. Careful analysis of the data is required to draw conclusions, reduce errors, and identify trends. The survey process and the associated results should be clearly documented for quality assurance. Any errors or biases identified in the research should also be accurately reported.

The development of this socio-acoustic survey should consider the information given in this section but with acknowledgement that alternative solutions may be justified.

2.2 Noise exposure results

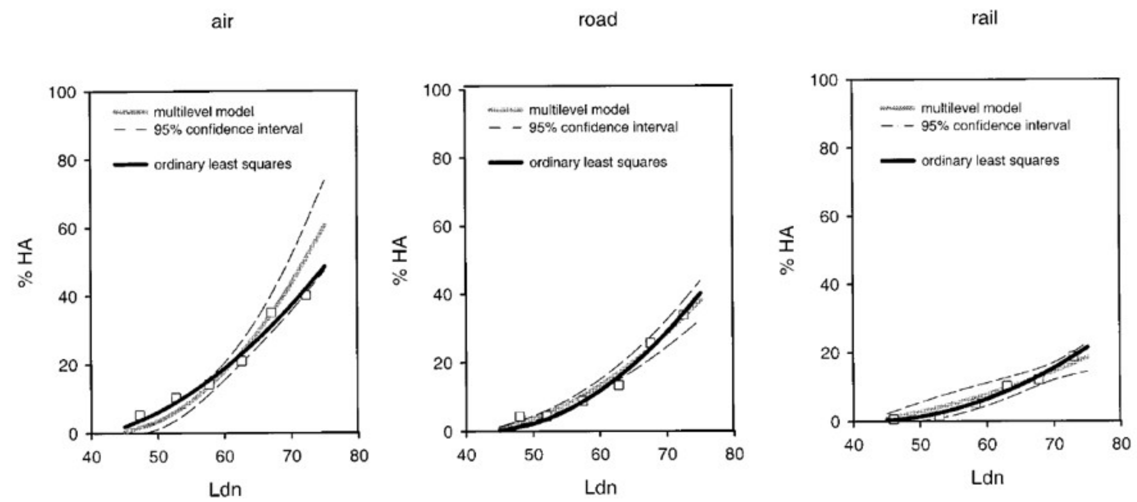
A large number of socio-acoustic surveys have been undertaken with the aim of improving the overall understanding of annoyance due to transportation noise. Numerous authors have performed independent surveys and meta-analysis of existing studies. The research performed by Miedema and Vos (1998) represents a large step in the development of dose-response curves for noise annoyance. This research presents a meta-analysis of the 21 data sets presented by Schultz (1978) and Fidell et al (1991), augmented with a further 34 datasets.

On a five-point scale, the descriptors are usually 'not annoyed', 'slightly annoyed', 'moderately annoyed', 'very annoyed' and 'extremely annoyed'. Schultz developed a relationship between the percentage of people choosing the top two descriptors ('very annoyed' and 'extremely annoyed', which are combined within the term 'highly annoyed') and residential noise exposure. Schultz defined 'highly annoyed' respondents as those whose self-described annoyance fell within the upper 28% of the response scale.

In order to develop a dose-response curve the percentage of respondents who reported being 'highly annoyed' (%HA), was calculated for the responses with an annoyance scale result of greater than 72/100. This cut-off value of 72 was used by Schultz and has persisted for comparison reasons.

Three separate dose-response curves were produced for three source types: road traffic, rail traffic and aircraft noise. An ordinary least squares line and a multilevel model were produced for the three data sets. The resulting curves are presented in figure 2.1.

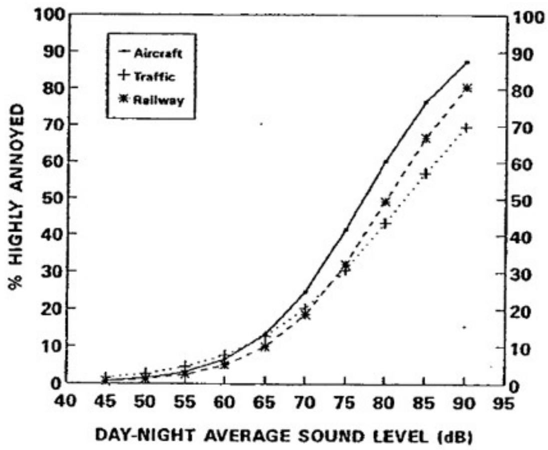
Figure 2.1 %HA as a function of Ldn. Two synthesis curves per mode of transportation and the data points are shown. For curves obtained with multilevel analysis the 95% confidence intervals are shown.



Source: Miedema and Vos (1998)

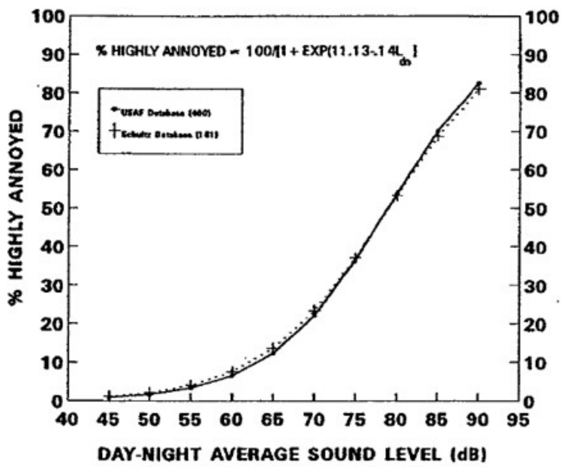
The annoyance caused by aircraft noise was found to be significantly higher than that for either road or rail noise, which may be due to both acoustic and non-acoustic factors (such as noise sensitivity, age and housing conditions). Large variations were found in data for the same noise source which was partially due to different types of source, for example motorways or urban roads. Other acoustic and non-acoustic factors also resulted in increased variations within survey results. It was shown that below approximately 45 dB L_{dn} zero annoyance was predicted and above this the %HA could be predicted based on the L_{dn}. A similar meta-analysis was performed by Finegold et al (1994) also using the data from Schultz (1978) and Fidell et al (1991). The data was re-analysed and dose-response curves determined as in figures 2.2 and 2.3. As with the Miedema and Voss analysis, the annoyance due to aircraft noise was higher than that due to road and rail noise, especially at higher noise levels, and the onset of significant annoyance occurred at marginally higher levels of noise.

Figure 2.2 HA vs day/night level (DNL) from aircraft, road traffic, and railway noise



Source: Finegold et al (1994)

Figure 2.3 Logistic fit to 400 community annoyance social survey data points and 1978 Schultz curve



Source: Finegold et al (1994)

In previous studies there was a large variation in the measured annoyance. Stewart (2000) reviewed the methods used to assess aircraft noise in an effort to evaluate the reasons for these variations. This review focused on common issues encountered during these assessments. Four major areas were investigated:

1 The difference between aircraft and traffic noise

2 Prior experience of respondents with noise and existing community noise

3 Differences between small and large airports

4 Issues in using an energy average for event type noise.

An evaluation of the work originally undertaken by Schultz (1978) identified some of its limitations and the way preceding authors interpreted Schultz's work. The assumption that Schultz's curves could be applied in all situations was found to have little or no supporting evidence. Furthermore, the lack of investigation into non-acoustical factors significantly limited the applicability of this work to a wider range of environments.

In contrast, the work by Fidell et al (1994) began to explore the impact of other factors on the community annoyance levels. It was shown that quieter communities are more susceptible to noise annoyance than communities with higher existing noise levels. This factor is also influenced by the fact that quieter communities are often rural rather than urban, and the residents of these communities have different expectations of their soundscape.

Air traffic has been shown by previous authors (see figures 2.1 to 2.3) to be significantly more annoying than road or rail traffic noise. Stewart (2000) showed that this effect is magnified at above 60 dB L_{dn}, and the %HA approaches zero near 45 dB L_{dn}. In the region between zero annoyance and 60 dB L_{dn} the annoyance due to aircraft noise is poorly defined as the data is limited.

The annoyance caused by air traffic at small airports was observed to be greater than that of larger airports. At 65 dB L_{dn} the number of people highly annoyed near a small airport measured to be 50%, whereas Schultz's curve predicted only 15% highly annoyed due to air traffic noise.

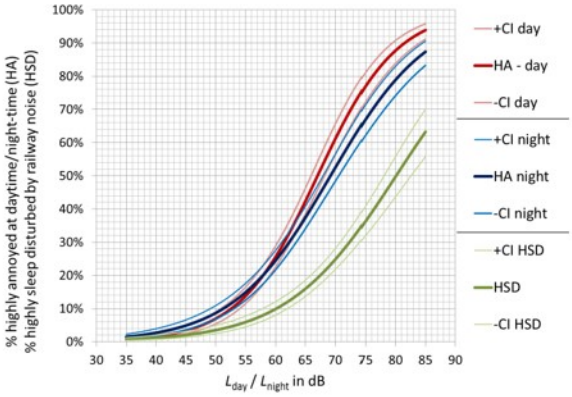
While studies have attempted to investigate the influence of events versus L_{dn} the results of these studies have often been conflicting. In general a dB comparison is often made between the number of events, with scales that range between 15–33 dB for a louder event to equal that of 10 quieter events. The L_{dn} was found to be less suitable for predicting the influence of increasing numbers of events on annoyance, particularly when the events were intermittent. Thus L_{dn} may be appropriate for road and rail noise, but less applicable to aircraft noise.

The most significant conclusion made by Stewart (2000) concerned the lack of reliable and easily comparable studies. Large variations between areas and populations, and insufficient research means it is difficult to account reliably for these variations. Furthermore, Stewart suggested that the differences between different areas and groups should be investigated further, especially when background noise levels were significantly different.

Schreckenberg (2013) presented a study on annoyance and sleep disturbance due to railway noise in the Rhine Valley. The Rhine Valley has been subjected to a significant increase in rail traffic, and the area is a target of a noise control programme. Part of this noise control programme was to undertake studies on noise annoyance in the community. Participants were chosen using a random selection of houses within a geographically defined area; and an individual inhabitant of the house was selected using the last-birthday method. A total of 1,005 residents were interviewed via telephone with a response rate of 41%. In order to improve the spread of data, supplemental sampling was performed in high-noise areas (above 60 dB $L_{Aeq(24h)}$) yielding another 206 participants. Responses to annoyance and sleep disturbance were measured using a five-point verbal scale. The ratio of passengers to freight was not explicitly defined in the paper.

The dose-response curve for highly annoyed participants was calculated according to the definition of Miedema and Voss (1998) using an annoyance level of 72/100. The five-point survey scale was converted by setting all responses with a score of 5 and 40% of responses with a score of 4 to be highly annoyed. The dose-response curve is reproduced in figure 2.4. The results of this study indicate that measurable noise annoyance persists below 45 dB in some situations. Details on the geographical and housing factors will be discussed later in this chapter.

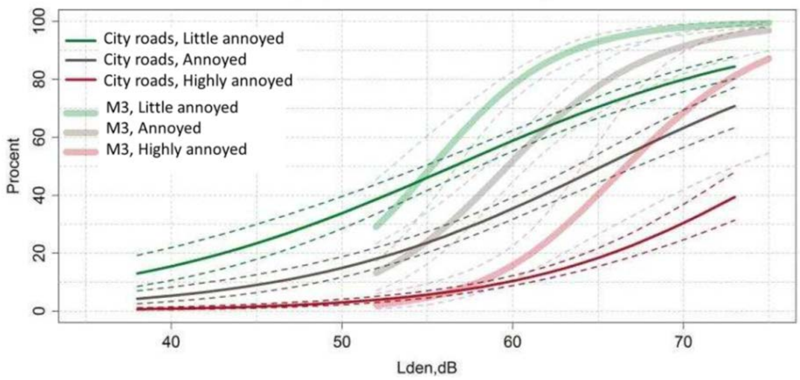
Figure 2.4 Logistic regressions for the percentage of people in the Rhine Valley highly annoyed by railway noise at daytime (HA day) against L_{day} and highly annoyed at night (HA night), as well as highly sleep disturbed by railway noise at night time (HSD) against L_{night}.



Note: In this figure, according to the ICBEN recommendations annoyance and disturbance response values above 3 on the 5-point response scale are defined as HA and HSD, respectively.
Source: Schreckenberg (2013).

Bendtsen et al (2014) presented a study that investigated the differences in noise annoyance between motorways and urban roads. Two studies were used; one near a motorway around Copenhagen and one near two urban roads within Copenhagen. The study distributed self-reported questionnaires, and received a total of 2,870 responses. This survey data was combined with modelled noise exposures to develop annoyance dose-response curves. The two sets of dose-response curves are given in figure 2.5. At noise exposures above 55–58 dB L_{den} noise from the motorway was perceived to be more annoying than that of urban roads at the same levels.

Figure 2.5 Average curves before and after situation. Urban streets (thin curves) and M3 (bold curves). The dashed lines indicate 95% confidence intervals.



Source: Bendsten et al (2014)

The results of the study were also compared with international annoyance dose-response curves. It was found that noise annoyance due to urban city roads has been well modelled, but the noise annoyance from the motorway was significantly higher than predicted. It was also found that greater than predicted reductions in the noise annoyance level were measured near the motorway following remedial work designed to lower noise levels. It is suspected that the expectations of the residents played a large part in this greater reduction in annoyance, due to the large visible noise barriers, information campaign and knowledge about noise-reducing pavements.

An assessment of the influence of traffic density, ground vibration, and building conditions on annoyance from rail noise was performed by Gidlöf-Gunnarsson et al (2012). This study used a written mail questionnaire to assess noise annoyance following ISO 15666. The survey was undertaken in Sweden, and focused on three areas, all of which were exposed to high rail noise levels but different levels of ground vibration. Noise levels and vibration levels were sampled in the areas surveyed. A total of 1,695 participants were surveyed and the overall response rate was 53%. Table 2.4 shows the variation of rail traffic types.

Table 2.4 Composition of train traffic at study sites

Train types	Area 1 no vibrations	Area 2 vibrations		Area 3 Many trains
	Töreboda / Falköping	Alingsås	Kungsbacka	Sollentuna
Number of trains/24h	124	206	179	481
Passenger trains:	78	153	154	446
Commuter trains (electrical multiple units)	32	105	146	155
Electrical locomotive with passenger cars	16	16	2	103
High speed trains	30	32	6	188
Freight trains / infrastructure service trains	44/2	48/5	22/3	15/20
Number of parallel tracks	2	2	2	4

Source: Gidlöf-Gunnarsson et al (2012)

The annoyance due to a similar noise exposure was measured to be higher when significant ground vibrations were caused by rail traffic, the resident had a patio or balcony facing the railway, or when rail traffic became very heavy. Increases in ground vibration are likely to increase the residents' fear of the noise source and damage it may cause, therefore increasing their annoyance. The presence of a balcony or patio oriented towards the railway is likely to result in higher noise exposure as the resident moves throughout their home.

Finally, as the number of trains becomes very high (up to 800/24 hour in Japan) the quiet time between noise events is reduced, resulting in significantly higher noise annoyance than predicted by Miedema and Vos (1998). The measured increase in annoyance over the predicted responses is very likely to be because the original curves were performed when rail traffic densities were significantly lower. This effect indicates that the 'rail bonus' normally applied in the EU may not apply when traffic volumes become very high.

Schreckenburg et al (1999) compared the annoyance due to rail and road traffic. The authors performed 1,600 interviews and measured noise in eight locations. The authors did not produce dose-response curves, but they did compare annoyance levels with those predicted by earlier research. It was found that rail resulted in lower annoyance levels for the same noise exposure, as predicted in the majority of previous research. This study was undertaken on rail lines that had fewer than 260 trains per 24 hours, and with a restricted maximum speed of 200 km/h. The proportion of freight traffic was less than 67%. A study by Jong and Miedema (1996) concluded there was not a constantly measureable difference in the dose-response curves due to the type of rail traffic. It was found that respondents were more likely to state that freight caused more annoyance, but this was not correlated by the measured results.

The annoyance due to industrial noise, traffic noise and the combination of both noise sources was assessed in a socio-acoustic survey by Pierrette et al (2012). An increase in annoyance with increasing noise levels was observed for all the noise sources evaluated, and overall traffic noise caused more annoyance than industrial noise. Respondents also reported different annoyance patterns for both noise sources, because traffic noise varies throughout the day whereas industrial noise is relatively constant.

2.3 Geographical and social effects

Inherent variation exists between any socio-acoustic survey, two of the largest contributing factors to variations between surveys are the geographical location of the survey and individual human factors. Several publications have investigated these factors, and the conclusions of these publications are discussed below.

In all socio-acoustic surveys there is the possibility of inherent bias being present when selecting sample populations as the presence of high levels of traffic noise will directly impact property values (Nelson 1982) and therefore the likely socio-economic status of the inhabitants. Despite this bias, the scale of road networks and the broad spectrum of exposure levels mean that with sufficient experimental design it is possible to ensure a suitably varied sample of a population is captured during a community noise survey.

Fields (1993) identified five social factors that can significantly affect the results of a socio-acoustic survey. These five factors were:

- fear of danger from the noise source
- noise prevention beliefs
- general noise sensitivity
- beliefs about the importance of the noise source
- annoyance with non-noise impacts of the noise source.

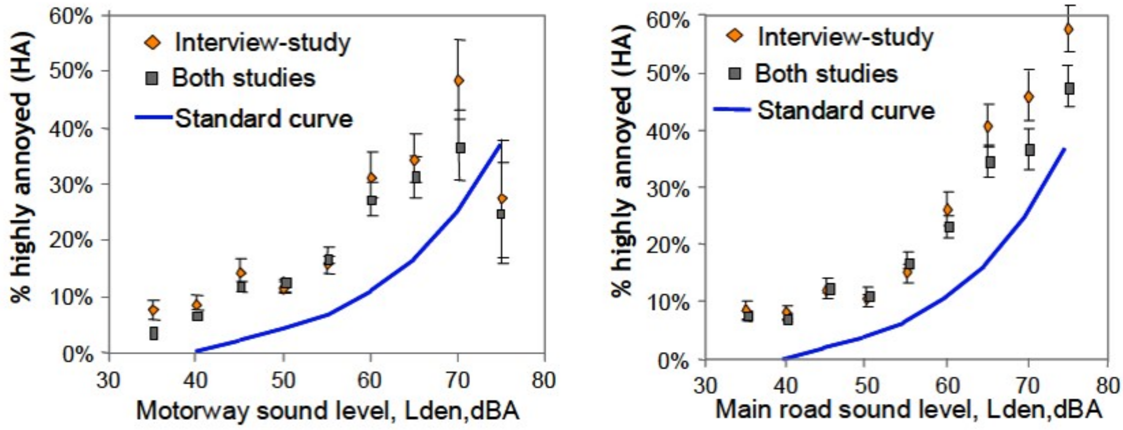
The research by Fields was unable to identify how the existing noise environment would influence annoyance based on new noise sources.

Lercher et al (2008) give an example of geographical influences. Their research investigated the differences between noise annoyance exposure-response curves evaluated in Alpine areas and the European standard curves (Miedema and Vos 1998) and (Miedema and Oudshoorn 2001). The discussion by the authors highlights some of the major limitations present in the application of standard curves to smaller populations:

- large variations in the responses within individual studies
- variations due to existing community noise levels
- variations in different countries
- variations due to local geography
- variations due to different noise sources.

The research focused on two areas, the Unterinntal and the Wipptal, both of which are in German Alpine valleys and have seen substantial increases in goods traffic over the past 25 years. Two studies were performed in the Wipptal (one phone and one face to face, with a total of 2,630 participants) and one phone survey in Unterinntal (with a total of 1,643 participants). The resulting exposure effect curves are reproduced in figure 2.6.

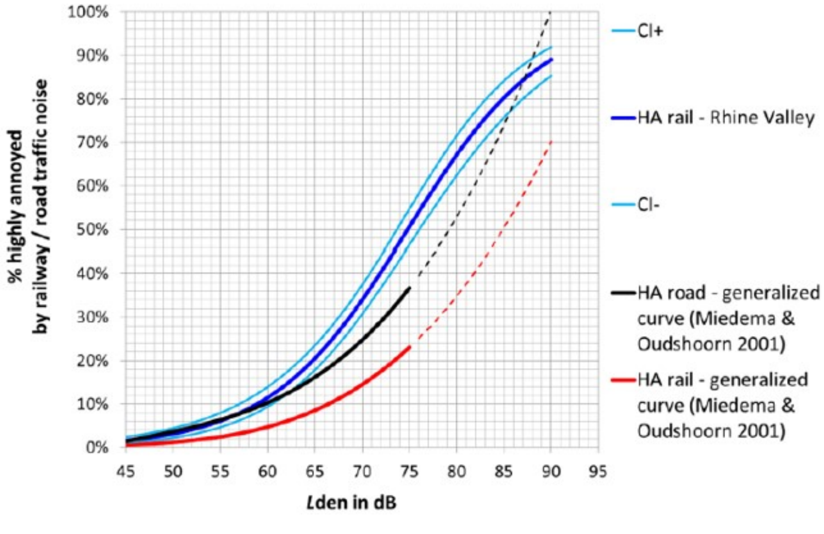
Figure 2.6 Exposure effect relationships: %HA by motorway (left) and main road sound exposure (right) by different noise modelling procedures compared with the standard curve (European Parliament (2002). Vertical lines represent 95% confidence intervals.



Source: Lercher et al (2008)

The survey by Schreckenberg (2013), discussed in section 2.2, was performed in the Middle Rhine Valley which has a similar geographical layout. A comparison between the measured annoyance and the predicted annoyance of the two studies is presented in figure 2.7.

Figure 2.7 Logistic regressions for the percentage of people in the Rhine Valley highly annoyed by railway noise (HA rail – Rhine Valley) compared with the generalised exposure-response curves for the percentage of people HA rail and highly annoyed by road traffic noise (HA road) by Miedema and Oudshoorn against L_{den}. In this figure a cut-off point of 72 (on a response scale 0 – 100) is used for the definition of HA.

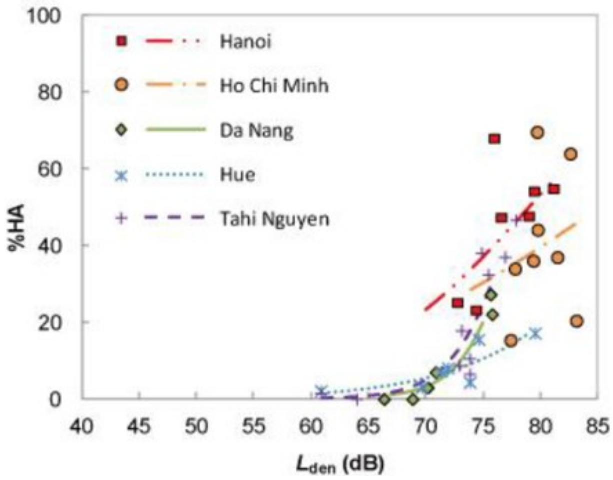


Source: Schreckenberg (2013)

The community noise annoyance level measured in both these surveys was significantly higher than those predicted by the European standard curve (Miedema and Vos 1998; Miedema and Oudshoorn 2001). The lower background levels, the direct propagation of noise to the valley sides, and the combination of road and rail noise are believed to be major causes of these variations. The observed differences in noise annoyance from the predicted levels are large despite the fact that the survey was undertaken on a sample within a European country. These variations highlight the large influence geography and location can have on the results of a socio-acoustic survey.

The results of an investigation by Shimoyama et al (2014) highlight the influence social factors can have on measured annoyance exposure response curves. This study was performed in Vietnam via a face-to-face survey of 4,966 residents and achieved a response rate of 64%. The study assessed residents exposed to noise levels from 61–83 dB L_{den} and from 50–73 dB $L_{Aeq,22\text{-}07}$[2]. The survey responses were used to produce %HA exposure response curves, which are given for the five cities in figure 2.8.

Figure 2.8 Comparison of exposure-response relationships among cities



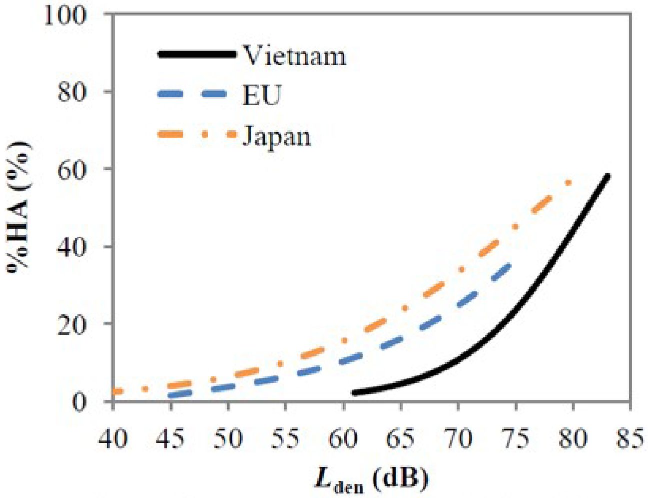
Source: Shimoyama et al (2014).

These exposure response curves were combined and compared with response curves from the EU and Japan, as shown in figure 2.9. The results of which indicate that Vietnamese respondents are 5–10 dB less annoyed by road traffic noise than those of the EU (Miedema and Vos 1998) or Japan. A number of attitudinal and human factors were also found to influence the noise annoyance levels, including noise sensitivity, vibration sensitivity, use of vehicles, opinions on the safety of vehicles, and opinions on the importance of vehicles for society. These non-acoustical factors were all found to significantly influence the respondents' annoyance levels.

It was found that if respondents believed the use of vehicles was good for society; their reported annoyance levels were reduced. Respondents with high noise sensitivity were found to suffer from significantly higher noise annoyance than those with low noise sensitivity. The largest influencing factor was noise sensitivity, with all the other factors having a small but measurable influence.

[2] 22-07 represents the night-time period from 10 pm to 7 am.

Figure 2.9 Comparison of exposure-response relationships among countries



Source: Shimoyama et al (2014)

A study performed by Lim et al (2006) evaluated the %HA in Korean cities. The sample was selected from residents in 18 areas along Gyungbu and Honam railway lines in Korea. Noise levels were measured at the survey sites, and a written questionnaire was used to assess community response to noise. This questionnaire assessed health effects and demographic questions as well as annoyance. The participation rate was 61.7% or a total of 724 respondents.

The makeup of the rail traffic and the amount of trains that pass by is given in table 2.5. The rail traffic consisted of approximately 40% freight on both lines evaluated. The number of trains passing during the day was three to five times the number of trains that pass at night.

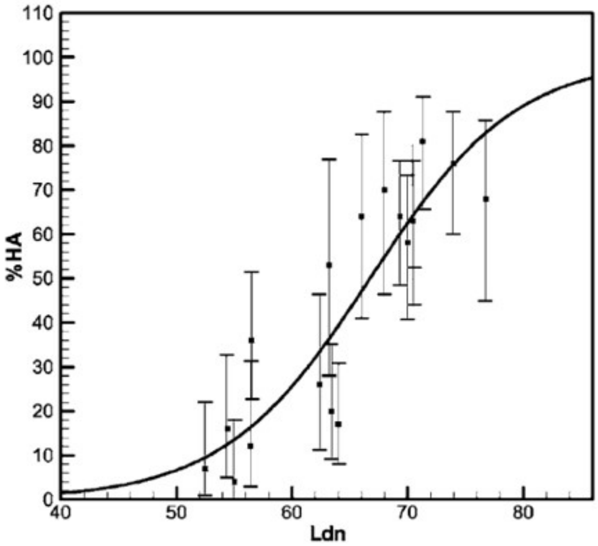
Table 2.5 Details of train movements, separated by type and time of operation

Line	Type of trains (diesel)		Number of trains per day	
	Passenger	Freight	Day time	Night time
Gyungbu line	152	98	178	72
Honam line	32	19	41	10

Source: Lim et al (2006)

The results of the survey were used to produce the dose-response curve in figure 2.10. This curve used the definition of 'highly annoyed' for the top 27–28% of the annoyance scale (this corresponds to the standard 72/100 typically used to define %HA). The large confidence intervals are typical of socio-acoustic surveys, and are due to the factors discussed throughout this literature review.

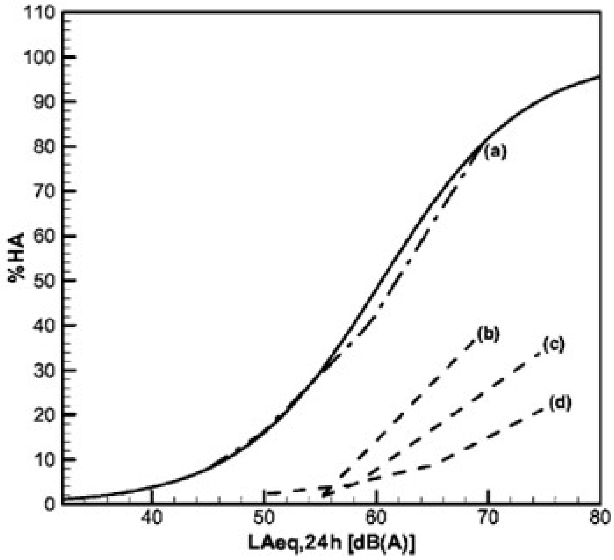
Figure 2.10 Prediction curve for the %HA based on noise exposure at the dwelling. Solid line is %HA prediction curve. Points are field survey data in 18 areas. Bars are 95% confidence intervals for the data point. *N*=613.



Source: Lim et al (2006)

The dose-response curve presented above is compared with dose-response curves from a range of different regions in figure 2.11. It is clear from these results that Korean residents are significantly more annoyed by railway noise than European residents. This could be due to a wide range of factors and its exact cause was not identified.

Figure 2.11 Comparison between the %HA prediction curve of railway noise in this study and those in other country surveys. [%HA prediction curve in this study; (a) Japan 1992; (b) France 1988; (c) Denmark 1988; (d) UK 1984].



Source: Lim et al (2006)

The age of respondents can influence the dose-response curves. A study by Babisch et al (2013) indicated that 8–10 year old children were significantly less annoyed by road traffic noise than adults. In contrast, a study undertaken by Kamp and Davies (2013) identified children among a list of vulnerable groups. Kamp and Davies also found that elderly respondents were less likely to be annoyed by noise, likely due to the natural degradation in human aural capacity that occurs with age. The elderly were found to be more susceptible to the negative cardiovascular effects of noise exposure.

A major non-acoustic factor is the respondents' trust in authorities and the belief that these authorities will do something about the noise should a complaint be made. This factor was studied indirectly by Henry and Huson (2004) in a community noise study undertaken in Brisbane, Australia. A total of 450 people were interviewed via telephone, after being selected at random using phone numbers within Brisbane city. On average the interview took 25 minutes and 4,120 phone calls were required to complete the required 450 interviews. Due to the lack of a noise level survey this study did not produce a dose-response curve. Traffic noise was found to be of the greatest concern to residents, but was not subject to the highest number of complaints (which was barking dogs and building construction). This is related to what the residents felt their complaints could achieve, and whether the authorities would act on their complaints.

Further research into a resident's belief that their complaints would create a meaningful change found that residents who mistrusted authorities' willingness to make meaningful changes in response to complaints had higher annoyance levels and a greater fear of increasing noise levels (Schreckenberg et al 2001). This reinforced the importance of full and honest notification and discussion with affected residents for minimising future annoyance.

Authorities were defined as both authorities that planned and undertook transport actions, the manufacturers of vehicles and equipment, and public authorities. The amount of information residents received prior to modifications resulted in a small but measurable improvement in the reduction of noise annoyance. The impact of the different authorities' attitudes was not investigated in this study.

The influence of mistrust was discussed by Borsky (1961), where it was described as a belief that complaints will be ineffective. Two thirds of people who complained about air operations, believed their complaint was 'a waste of effort'. This may reduce the number of actual complaints lodged, but will adversely influence community noise annoyance levels.

An overview of the impact that lack of trust has was presented by Guski (1999). The amount of trust associated with a particular noise source is influenced by residents' perceived control of the noise source, and how their complaints are handled by the controlling authority. For example, a significant increase in community noise occurred at Duesseldorf Airport in Germany following the sale of the airport to a private company and the number of complaints increased. A number of factors were in play following the change in ownership, but whether there was mistrust in the 'new management' cannot be proven. Nevertheless, community trust in the controlling authority, and therefore the resulting noise annoyance, can be improved when noise authorities show:

- clear data about the acoustic situation and its development
- an acceptance of the existence of harmful effects of noise
- clear data on abatement programmes
- a willingness to communicate with the residents.

The Genlyd noise annoyance model evaluated a range of factors that can influence the outcome of a socio-acoustic survey and incorporated these into a model for noise annoyance (Pedersen 2007). The actual model developed is beyond the scope of this literature review[3], but the report has a detailed

[3] This noise model was extensive in nature and much of it was focused on developing a complex statistical model. If the reader is further interested they are advised to access the article at: http://share.madebydelta.com/publikationer/

discussion of factors that modify annoyance levels. A more detailed study of the research undertaken by the same author presented the survey data used to develop these modifying factors (Pedersen et al 2014). A rating of the impact of different non-acoustic factors is presented in table 2.6.

Table 2.6 The approximate maximal noise equivalent effect in dB of the effect on transportation noise for different variables

Variable	Approximate noise level equivalent dB	Variable	Approximate noise level equivalent dB
Fear	19	Household size	2
Noise sensitivity	11	Use of noise source	2
Age	5	Home-ownership	2
Dependency on sound source	2	Occupation	1
Education	2	Gender	0

Source: Pedersen (2007)

When a resident has some fear of a noise source or what that noise source may do they suffer much higher noise annoyance. This is because the fear makes these people more aware of the relevant noise source. The influence of noise sensitivity is also very large, which is expected as these people are affected by all noise sources to a greater extent. Age-related noise annoyance has previously been shown to peak at middle age and is a major factor in annoyance results.

A report by Schomer (2005) presented a detailed analysis of the results that have been found in relation to annoyance from traffic noise. Schomer concluded that despite the large variations between the socio-acoustic surveys, reliable trends are seen in most studies. These common trends indicate that there is a strong correlation between noise levels and community annoyance.

The effectiveness of day/night levels (DNL) was questioned by Schomer based on previous studies that found other descriptors (such as $L_{A,eq}$) might result in better correlations with community noise. The choice to use any other descriptor would result in a significant reduction in the number of available comparative studies. For this reason if other descriptors are to be used, the DNL should also be evaluated for comparison with existing data.

Schomer identified survey structure and non-acoustic factors as the leading causes of variation within surveys. These variations need to be accounted for during the design stages of the research. Survey structure and methodology is a controllable variable that can be accounted for prior to data collection. Non-acoustical factors are intrinsic to the community surveyed, but adequate data should be collected on these factors to account for them.

A survey undertaken in New Zealand by Welch et al (2013) studied the impact road traffic noise had on health-related quality of life. The survey used a written survey which respondents filled out and returned using a pre-paid envelope. This survey was distributed to 1,250 houses and yielded 502 responses. The survey estimated noise exposure levels from road traffic data. Although dose-response curves were not generated, the relationship between noise annoyance and poor health outcomes was assessed. It was found that noise-sensitive persons are more likely to have poor health outcomes when they are exposed to excessive noise levels.

An extensive survey conducted in Germany investigated the impact of social differences on observed noise annoyance (Laußmann et al 2013). This study assessed annoyance for a total of 8,152 persons, with a response rate of 42% for first-time respondents and 62% for revisiting participants. Noise annoyance and road traffic intensity were assessed using self-administered questionnaires. The survey also assessed housing types, educational background, age, sex, disposable income and occupation.

Road noise was found to have the largest amount of annoyance among the participants; this was followed by neighbourhood noise and aircraft noise. The study found that all participants from low-income households were more frequently exposed to and felt more severely affected by road traffic noise. Respondents from larger cities and areas with high population densities also reported higher annoyance levels due to road traffic noise. Similar trends were seen for neighbourhood noise and to a limited extent aircraft noise.

The primary conclusion of this study was that exposure to environmental noise is not equally distributed among different groups in German society. This is because people in low-income households are often only able to afford housing that exists within areas that have high noise exposure levels. The study did not perform noise measurements and as such dose-response curves could not be generated.

2.4 Health effects of noise exposure

While this literature review is primarily focused on community annoyance due to traffic noise, the health effects of noise exposure are important to note. The WHO identifies noise as a harmful environmental pollutant (Berglund et al 1999). The harmful health effects listed by the WHO are:

- noise-induced hearing impairment which is due to high noise levels
- sleep disturbance
- cardiovascular effects such as hypertension and ischaemic heart disease
- mental health effects such as stress, anxiety, psychosis and hysteria.

The majority of studies have focused on the cardiovascular impacts of increased noise exposure. A comprehensive review of the relation between traffic noise and cardiovascular disease was performed by Selander (2010). An increased risk of heart attack (myocardial infarction) was seen in residents who were exposed to road traffic noise exceeding 50 dB, which was similar to research by Beelen et al (2008); Babisch et al (2005); and Babisch (2000) who observed a similar response at levels above 65 dB and 70 dB respectively. The prevalence of high blood pressure (hypertension) in a community was observed to increase as traffic noise levels increased.

Sleep disturbance is a common complaint associated with noise annoyance. Numerous authors have studied the impact of increased noise levels on sleep disturbance (Kim et al 2012; Passchier-Vermeer and Passchier 2000; Pearsons et al 1995). In both laboratory and socio-acoustic surveys, increased noise levels were observed to result in more sleep disturbances. Increased sleep disturbances result in changes in the cardiovascular system, tiredness, reduced sleep quality, and changes to hormonal and immune systems. The review presented by Ouis (1999) evaluated the documented impact of noise on sleep disturbance and the corresponding after effects. It was found that noise-induced sleep disturbances were accumulative and over time would result in reduced cognitive abilities. It has also been shown that increased sleep disturbances cause increased stress responses, and can negatively impact on hormonal systems in persons exposed to high noise levels (Zaharna and Guilleminault 2010).

A study undertaken in New Zealand showed that road traffic noise was responsible for significant decreases in health-related quality of life (Welch et al 2013). This study found that the largest impact occurred when noise sensitive persons were exposed to high levels of noise. It was also found that noise annoyance was a strong indicator of noise sensitivity.

Increased road traffic noise has been attributed to a range of other health effects, including but not limited to:

- increased risk of obesity (Pyko et al 2014)
- insulin resistance, stress-ulcers (Ising and Kruppa 2004)
- reduced cognitive development and performance in children (Clark et al 2005; Clark et al 2012).

In conclusion excessive environmental noise has been shown to have a wide range of negative health consequences. The actual noise level at which these effects begin to occur are subject to significant debate, but appear to lie within the levels often caused by road and rail traffic noise. Noise annoyance appears to be related to many of these health outcomes and is relatively simple to measure via socio-economic surveys.

This review of existing literature identified a range of aspects requiring careful consideration during the design phase of the noise survey. It was important to ensure the survey was repeatable, reproducible and able to be compared with prior surveys of noise annoyance.

2.5 Summary

2.5.1 Suitable criteria

Within the literature a wide range of acoustic criteria has been used to measure noise exposure or noise levels receiver locations. The two major criteria used in community noise studies are day/night average sound level (L_{dn} or DNL) and the community noise equivalent level (L_{den} or CNEL). The DNL is used to quantify traffic noise, whereas the CNEL is used for quantifying industrial or traffic noise in the community. The $L_{Aeq(24hr)}$ criteria has also been used by some authors and is the criteria included in NZS6806:2010.

2.5.2 Measurement and modelling

A sufficiently accurate model of the noise distribution throughout the survey area is required to ensure that the survey results are correctly correlated with the noise exposure levels. This model will require field measurements of the noise levels, traffic data and information about the road surfaces. The accuracy of the modelled noise levels should be within 2 dB to allow comparisons with the existing models. Ideally, these models should be verified against logged noise measurements to ensure their accuracy.

2.5.3 Interview design

At the outset of the research study, it was decided a telephone interview methodology would be the best compromise between response rate, cost and survey programme implications. Phone interviews in New Zealand typically provide moderate response rates (generally between 40% and 60%), good quality data for reasonable time and financial cost in comparison with other survey techniques.

The development of a suitable set of survey questions should use ISO/TS 15666 (ISO 2013) for guidance, but this standard does not provide a detailed survey design. The use of the ISO/TS 15666 standard question for noise annoyance should be used as it represents good international practice. It is important that adequate supporting information, such as basic personal information, including age, sex and race, is gathered during the interview, as well as major modifiers, such as:

- fear of harm due to noise source
- noise sensitivity
- perception of vibrations due to noise source
- visual impact of noise source

- belief that authorities will act on complaints
- education level
- financial situation.

The collection of sufficient data is also a balance of risk, as an excessively long or complex interview may result in lower response rates or reduce the quality of the data gathered. An upper limit of 30 minutes is suggested for phone interviews. It is also important that complex questions are placed early or near the middle of the interview to ensure the respondent is not tired.

The use of long lists of possible answers is not recommended for phone interviews as they may be difficult for the interviewee to remember. For questions with a list of verbal answers, five possible answers are suggested; for numerical scales only the maximum and minimum values are required. It is suggested that all the annoyance questions are structured in a negative-neutral manner and an 11-point 0 to 10 scale is used for numerical scales as these are relatively common. In all cases care should be taken to ensure that the verbal labels used are clear and not ambiguous in meaning.

2.5.4 Sample selection

The selection of a suitable sample for this survey should consider the following factors: noise levels, socio-economic distributions, geography and building types. An effort should be made to sample a reasonable number of respondents from a range of different situations. It is likely that achieving an ideal socio-economic cross section will not be possible due to the relationship between high noise levels and financial means, but all possible endeavours should be made to quantify the influence of these factors.

The minimum noise level of 45 dB L_{dn} has been shown to yield a sufficiently wide spread of noise annoyance data; this is supported by the results presented in table 2.7. In developing this sample set it is important to ensure that a sufficiently large number of respondents reside in areas with high noise levels. A randomised geographical sample is unlikely to satisfy this criterion as areas of high noise exposure are less extensive than areas of low noise exposure, this may necessitate resampling at higher densities in these areas of high noise exposure.

Table 2.7 Comparison of minimum noise level at which noise annoyance is measurable and correlated with noise levels

Reference	Minimum noise level for annoyance	Noise source	Notes
Langdon (1976)	60 dB L_{A10}	Road	High nuisance measured above this level
Miedema and Vos (1998)	40 dB L_{dn}	Aircraft, road, rail	Minimum noise level where correlation is observed between noise and annoyance
Schultz (1978)	40 – 50 dB L_{dn}	Aircraft, road, rail	Results of large number of studies predicted zero annoyance within this range
Finegold et al (1994)	45 dB L_{dn}	Aircraft, road, rail	Minimum of prediction curves, results in near zero annoyance
Stewart (2000)	55 dB L_{dn}	Aircraft, road, rail	Measurable annoyance levels below this noise level
Schreckenburg et al (1999)	40 dB	Rail, road	Used as minimum level for performing survey
Bendsten et al (2014)	40 dB L_{dn}	Road	Measurable annoyance to levels below this value
Lercher et al (2008)	35 dB L_{den}	Road, rail	Measured annoyance to this level

Reference	Minimum noise level for annoyance	Noise source	Notes
Shimoyama et al (2014)	60 dB L_{den}	Road	Minimum annoyance observed at this level
Lim et al (2006)	55 dB L_{dn}	Mixed	Study only measured down to this level
Schomer (2005)	50 dB L_{dn}	Mixed	Considered engendering moderate annoyance
Goines and Hagler (2007)	45 dB	Mixed	Measurable annoyance above this level
Gidlöf-Gunnarsson et al (2012)	45 dB$L_{Aeq(24h)}$	Rail	Measured annoyance down to this level
Jakovljevic et al (2009)	45 dB L_{den}	Road	Significant annoyance measured at this level

3 Study area selection

3.1 Survey areas

An aim of the study was to assess the dose-response changes between steady-state condition; ie long-term exposure to noise and the short-term changes that occur following the construction or change in a new or existing road or railway. The research project required three sites to be evaluated for community response to noise:

- one new or altered road study area
- one existing road study area
- one existing rail study area.

Initially, 18 roads were evaluated for their suitability as study sites, see appendix A. Twelve were new roads and six were existing roads, see table 3.1. These new roads had either opened or undergone major works in 2010 or later.

Due to a number of limitations the primary objective of assessing short-term changes could not be fulfilled and the research study design was adapted.

One of the original aims of the study was to assess a similar change in noise annoyance due to a new or recently altered rail study area. It became clear early on in the study that in New Zealand there had been no major changes to the rail infrastructure which would have satisfied this criterion. While new passenger trains introduced in Wellington (from late 2010 until 2015) and the electrification of Auckland (completed 2015) resulted in some changes to the existing noise environment, there had been no new rail routes introduced that would have led to a step-change in the receiving noise environment. Accordingly, the rail element of the study focused on a suitable existing area where there was the appropriate frequency of train movements and proximity and density of residential dwelling. Six passenger routes were identified and five major freight routes, see table 3.2 and appendix A.

The number of receivers within 500 m of each potential road and rail study area was assessed using geographic information systems data queries. The number and spread of receivers (building locations) was used as the main selector for suitable sites. Other factors considered in the selection of the shortlist were:

- High traffic flows were preferred due to the higher resulting noise levels (higher noise levels at greater distances from the road and higher noise levels close to the roads).
- Preference was given to roads that were opened most recently, ie any change in noise exposure/dose was potentially still quantifiable.

A number of the new roads initially investigated were rejected from the shortlist as a result of their completion date (eg SH 18 in Auckland), low number of potential receivers (eg SH 50 in Hawke's Bay) or the change to the road being relatively minor (eg Carmen Road in Christchurch).

Table 3.1 Screening selection – roads

Road	Location	Total number of receivers	Distance between receivers and road/ rail/metres					Traffic AADT	Completion date
			0–50	51–100	101–150	151–200	>201		
New roads									
Neilson St	Auckland	1,384	155	103	81	79	966	30,000	2013
Glenfield Rd	Auckland	1,913	122	107	166	194	1,324	21,000	2013
Tiverton and Wolverton	Auckland	2,780	210	190	220	287	1,873	27,000	2014
Manukau Extension	Auckland	1,839	2	65	106	142	1,524	40,000	2011
Carmen Rd	Christchurch	2,079	156	214	194	195	1,320	25,700	2014
CSM1	Christchurch	4,102	58	361	360	386	2,937	20,000	2012
Waikato Expwy	Hamilton	767	9	48	52	70	588	20,000	2012
Caversham Hwy	Dunedin	2,893	77	259	265	224	2,068	25,000	2012
SH18	Auckland	3,803	33	312	379	431	2,648	40,000	unknown
SH20 Onehunga	Auckland	5,600	75	341	493	625	4,066	50,000	unknown
SH60	Nelson	526	47	52	45	46	336	5,600	2010
SH50	Hawke's Bay	214	1	2	5	11	195	7,000	
Existing roads									
SH2 Lower Hutt	Wellington	4,539	174	490	344	376	3,155	40,000	unknown
SH2 Upper Hutt	Wellington	4,400	152	310	467	449	3,022	24,000	unknown
SH1 Johnsonville	Wellington	3,973	133	409	446	456	2,529	44,000	unknown
SH1 Porirua	Wellington	3,188	73	330	393	418	1,974	43,000	unknown
SH1 South Auckland	Auckland	25,681	696	2,958	2615	2774	16,638	95,000	unknown
SH1 North Auckland	Auckland	6,599	81	478	688	685	4,667	164,000	unknown

Table 3.2 Screening selection – rail

Rail	Location	Total number of receivers	Distance between receivers and road/ rail/metres					Average trains per day
			0–50	51–100	1011–50	151–200	>201	
Passenger lines								
Western	Auckland	23,962	2,024	2,759	2,353	2,311	14,515	104
Eastern	Auckland	9,133	514	800	781	1,001	6,037	128
Southern	Auckland	22,231	1,432	2,553	2,308	2,404	13,534	202
Hutt Valley	Wellington	15,726	1,049	1,713	1,824	1,664	9,476	75
Johnsonville	Wellington	8,012	428	844	885	881	4,974	80
Kapiti	Wellington	6,591	290	801	846	775	3,879	n/a
Freight lines								
Main trunk	Auckland	26,342	1,263	2,580	2,783	2,921	16,795	n/a
Main trunk	Wellington	6,591	290	801	846	775	38,79	n/a

Rail	Location	Total number of receivers	Distance between receivers and road/ rail/metres					Average trains per day
			0–50	51–100	1011–50	151–200	>201	
Main trunk (north)	Christchurch	8667	528	864	833	877	5565	n/a
Main trunk (east)	Christchurch	7507	434	653	700	793	4927	n/a
Main trunk (west)	Christchurch	4581	168	320	398	466	3229	n/a

During the site selection process it was identified that the number of receivers required to achieve a good statistical significance (low margin of error) meant some of the sites listed above were not viable. The target sample size for each study area was set at n=400, which corresponds to a margin of error of less than 5%. This is the minimum sample size accepted by most government agencies for their survey research. To significantly improve on this level of accuracy would have required the sample size to be tripled, which is achievable for the most densely populated study areas or by aggregating areas of lower population density. The aggregation method was not chosen as the study was concerned with measuring the change. The project team considered that each study area had to have at least 3,000 receivers based on the random sampling requirements of the study and potential success rate of undertaking a survey at each address location.

Table 3.3 provides a guide to the maximum margin of error at the 95% confidence level for different sample sizes. This data only applies to homogeneous population, ie where the sample does not differ in any relevant variable from the overall population. For example if 50% of the people interviewed said they were negatively affected by traffic noise, then at the 95% confident limit, the entire population affected by road traffic noise at that location would provide the same result, give or take 4.9%. The margin of error is therefore dependent upon the initial sample size.

For very low sample rates where high margins of error are likely, alternative interview techniques may be appropriate. Recently, more in-depth qualitative interviews have been conducted on smaller numbers of respondents. These one-to-one interviews while expensive to conduct are focused and can be less constrained by the format of a prescriptive interview structure.

Table 3.3 Margin of error at 95% confidence level

	Sample size						
	100	200	300	400	500	1000	2000
50%	9.8%	6.9%	5.7%	4.9%	4.4%	3.1%	2.2%
40%	9.6%	6.8%	5.5%	4.8%	4.3%	3.0%	2.1%
30%	9.0%	6.4%	5.2%	4.5%	4.0%	2.8%	2.0%
20%	7.8%	5.5%	4.5%	3.9%	3.5%	2.5%	1.8%
10%	5.9%	4.2%	3.4%	2.9%	2.6%	1.9%	1.3%
5%	4.3%	3.0%	2.5%	2.1%	1.9%	1.4%	1.0%
2%	(a)	1.9%	1.6%	1.4%	1.2%	0.9%	0.6%

(a) Standard calculation is not acceptably accurate

Following a Steering Group meeting on 12 October 2015, it was agreed that SH 1 in South Auckland would qualify as the existing road study area and Auckland's southern rail corridor would qualify as the rail study area. It was considered at the meeting that the suitability of using a Roads of National Significance (RoNS)[4] site in addition to the existing road and rail locations should be investigated. The RoNS site would be surveyed before opening (ideally before significant construction) and again after, once traffic flow characteristics had stabilised. The inclusion of a new road would assist with one of the prime study aims of assessing the change in noise environment following the opening of a new roading project. The scope of the research project was limited to surveying only the RoNS prior to completion of the project and hence this report does not address the change effect. The option exists to resurvey the study area once traffic flow conditions have stabilised, which is typically within a period of 12 to 18 months.

The RoNS projects offer an opportunity to undertake a large scale assessment of annoyance of new roads. Several of the above projects involve the introduction of either a completely new road or major modifications to existing roads. These major changes will result in a 'step change' in the noise exposure of nearby residents, potentially allowing the noise annoyance to be assessed before and after the project's completion.

Although there are seven major RoNS projects, an initial assessment was undertaken of a total of 29 sub-RoNS projects (stages).

3.1.1 RoNS overview

Table 3.4 provides a high-level overview of all the RoNS projects. This table was prepared prior to completion of the social surveys and hence some of the comments included are out of date. Each of the projects was assessed for suitability for the community response study. The factors that influenced the suitability of a project were:

- construction and opening dates
- the scale of the overall noise change to the existing road network
- the likely noise impacts of the project.

From this list a set of four projects were chosen for detailed analysis.

Table 3.4 RoNS projects overview

Overall project	Project stages	Description of stage	Is stage major modification?	Start date	Completion date	Suitable?
Puhoi to Wellsford	Puhoi to Warkworth	18.5 km new road	Yes	2016		Yes - depending on construction dates
	Warkworth to Wellsford	Likely to be a completely separate (from SH1) motorway	Yes			Yes - depending on construction dates
Western Ring Route	Waterview Connection	New roads + tunnel ring route	Yes	2014	2017	Yes
	SH 16 causeway upgrade	Raising and widening of motorway	No	2014	2017	No – not major change
	SH 16 Lincoln Rd interchange	Widening and upgrade of bridge	No	2013	Completed (2013)	No – already completed

[4] Defined in the former 'Government Policy Statement On Land Transport 2015/16–2024/25' as routes that have been nominated by the Government as critical to improving economic productivity and growth. Currently there are seven projects on the RoNS programme, based around New Zealand's five largest population centres. The focus is on moving people and freight between and within these centres more safely and efficiently.

Overall project	Project stages	Description of stage	Is stage major modification?	Start date	Completion date	Suitable?
	Te Atatu Rd Interchange	Raising of bridge and upgrade of access	No	2014	2016	No – not major change
	St Lukes Rd to Great North Rd	Widening of 2 km of road	Possibly sufficient changes	2014	2016	Depends on scale of change
	Auckland Northern Corridor	3-laning and road upgrades	Some areas may be	2014	2021	Depends on number of receivers and construction timeframes
	SH 16 Lincoln to Westgate	Addition of lanes and upgrades to existing road	Possibly sufficient changes	2016	2019	Depends on scale of change
Victoria Park Tunnel	N/A	Tunnel project	Yes		Completed	No - already completed
Waikato Express-way	Longswamp	Upgrade of existing SH1 to expressway standard	Possibly sufficient changes	2015	2018	Depends on scale of change
	Rangiriri	Upgrade and some deviation from SH 1	Possibly sufficient changes	Currently underway	2016	Depends on number of receivers and construction timeframes
	Huntly	Major deviation from existing SH 1, construction of expressway	Yes	Currently underway		Depends on number of receivers and construction timeframes
	Ngaruawahia	NA	NA	NA	Completed (2013)	No - already completed
	Te Rapa	NA	NA	NA	Completed (2012)	No - already completed
	Hamilton	Installation of 21.8 km of new road	Yes	2016		Depends on number of receivers and construction timeframes
	Cambridge	Significant new roads	Yes		2016	Depends on number of receivers and construction timeframes
Tauranga Eastern Link	N/A	21 km 4-lane highway	Yes	2010	Completed (2015)	No - already completed
Wellington Northern Corridor	Mt Victoria Tunnel duplication	Second tunnel and widening of road	Yes – but noise effects not relevant	2018	2022	Unlikely due to time frames
	Tunnel to tunnel inner-city transport improvements	Road upgrades and tunnelling	No	2013	2016	No – as not a new road

Overall project	Project stages	Description of stage	Is stage major modification?	Start date	Completion date	Suitable?
	Terrace Tunnel duplication	Second tunnel	Possibly sufficient changes	NA	NA	Unlikely as in early stages of investigation
	Smart Motorway	Technological upgrades	No	2015	2016	No major changes
	Transmission Gulley	New 27 km 4-lane motorway	Yes	Currently underway	2020	Depends on number of receivers and construction timeframes
	Peka Peka to Otaki Expressway	13 km of new and modified road	Yes	2016	2020	Depends on number of receivers and construction timeframes
	Otaki to north of Levin	Upgrade of existing SH 1	No	2019		Unlikely due to time frames
	Mackays to Peka Peka	18 km of new and upgraded motorway	Yes	Currently underway	Mid 2017	Depends on number of receivers and construction timeframes
Christ-church Motorways	Christchurch Northern Arterial	7 km of new road	Yes	2014	2016	Yes
	Christchurch Western Corridor	Improvement of SH 1 around Christchurch	Maybe	Currently underway		Depends on scale of change
	Christchurch Southern Corridor	New motorway in south Christchurch	Yes	Currently underway	2016	Yes - depending on dates

Four sites were selected for a detailed assessment from the list presented in table 3.4.

- Christchurch Motorways
- Auckland Western Ring Route (SH 20 Waterview connection)
- Waikato Expressway – SH 1
- Wellington Northern Corridor (Mackays to Peka Peka).

The number and distribution of nearby receivers was assessed in a similar manner to the assessment of existing roads and rail study areas. The results of this assessment are presented in table 3.5. The zoning and building use around the chosen alignment was assessed to evaluate if there would be a suitably large sample of residents. The number of residents within 200 m[5] of the alignments was calculated and broken down into four distance bands and a simplified assessment of road traffic noise levels was undertaken based on the existing traffic flow characteristics to determine the range of existing noise levels that could be experienced.

[5] A buffer distance of 200 m from the near edge of the carriageway

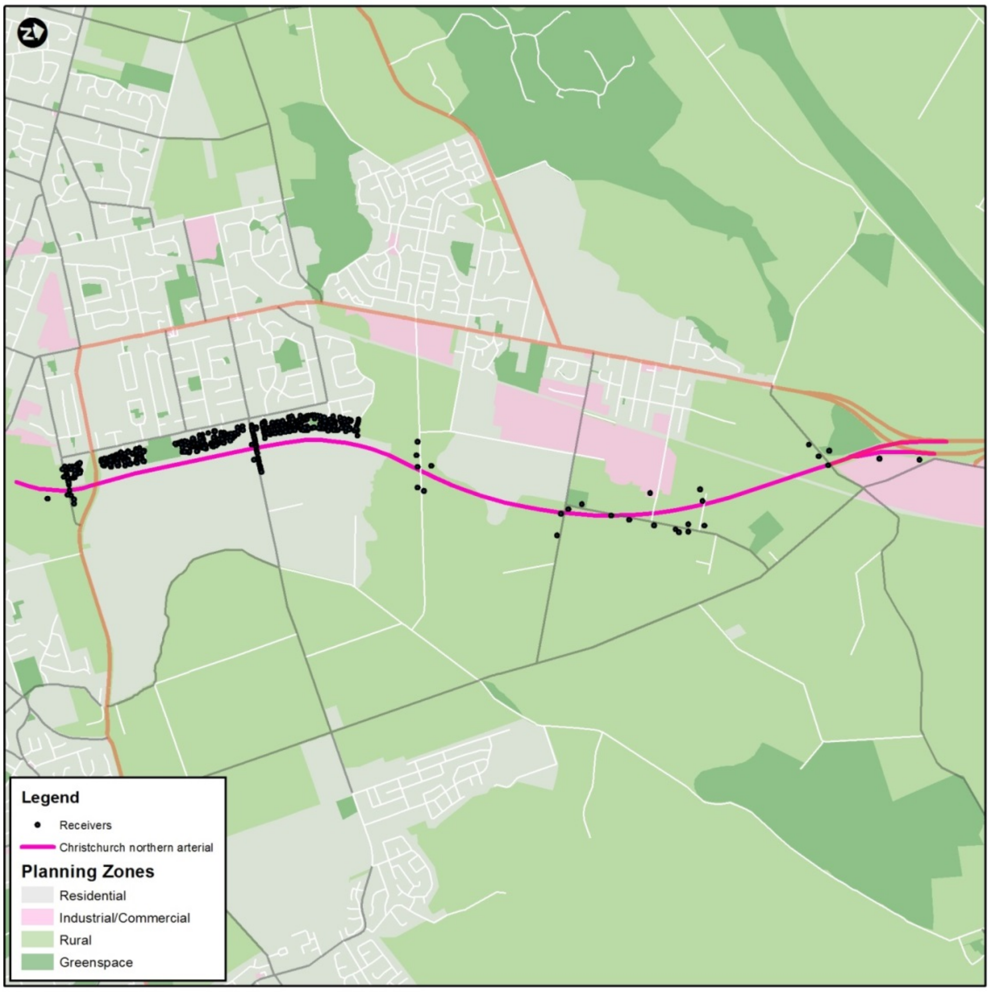
Table 3.1 Selected RoNS projects

	Christchurch	Auckland		Waikato	Wellington/ Kapiti Coast
	Northern Arterial	Waterview with North Tunnel exit	Waterview without North Tunnel exit	Cambridge Bypass	Mackays to Peka Peka
Receivers within 200 m	371	808	692	267	795
Receivers (<50 m)	18	89	66	23	34
Receivers (50–100 m)	83	159	129	78	191
Receivers (100–150 m)	136	228	195	83	268
Receivers (150–200 m)	134	332	302	83	302
AADT (current)	N/A	SH16: 47,123 SH20: 23,850		N/A	N/A
AADT (future)	42,000 (2026)	unknown		unknown	unknown
Residential zoning (approximate)	90–100%	80–90%		90–100%	80–90%
Completion date	2019	early 2017		late 2016	early 2017

3.1.2 Christchurch – Northern Arterial

The Christchurch Northern Arterial is a link from the north of Christchurch to the central city, also providing access to Lyttelton Port and Christchurch CBD. This project involves approximately 7 km of new motorway, most of which is being constructed at or near ground level. The area the project will pass through is primarily residential or rural, much of which is relatively sparsely populated. Queen Elizabeth II Drive crosses the project alignment at the southern end, meaning a relatively high noise environment already exists in this area.

Figure 3.1 Christchurch Northern Arterial



3.1.3 Auckland – Waterview Connection

The Waterview Connection (see figure 3.2) completes a motorway ring route around Auckland city which will connect the southwestern and north western motorways (SH 20 and SH 16). Half of the new motorway (2.4 km) will not create significant noise impacts as it is underground (Waterview Tunnel). There have also been modifications of the southwestern motorway south of the new motorway; which combined with the opening of the Waterview Tunnel will result in a significant increase in the overall traffic density on this route. The remaining section of the new motorway runs through an established residential area. There are a number of major roads near the new alignment that may contribute significant noise in the existing environment. These roads are:

- Main North Road
- Richardson Road
- Stoddard Road
- Dominion Road.

Figure 3.2 Waterview Connection

3.1.4 Waikato Expressway

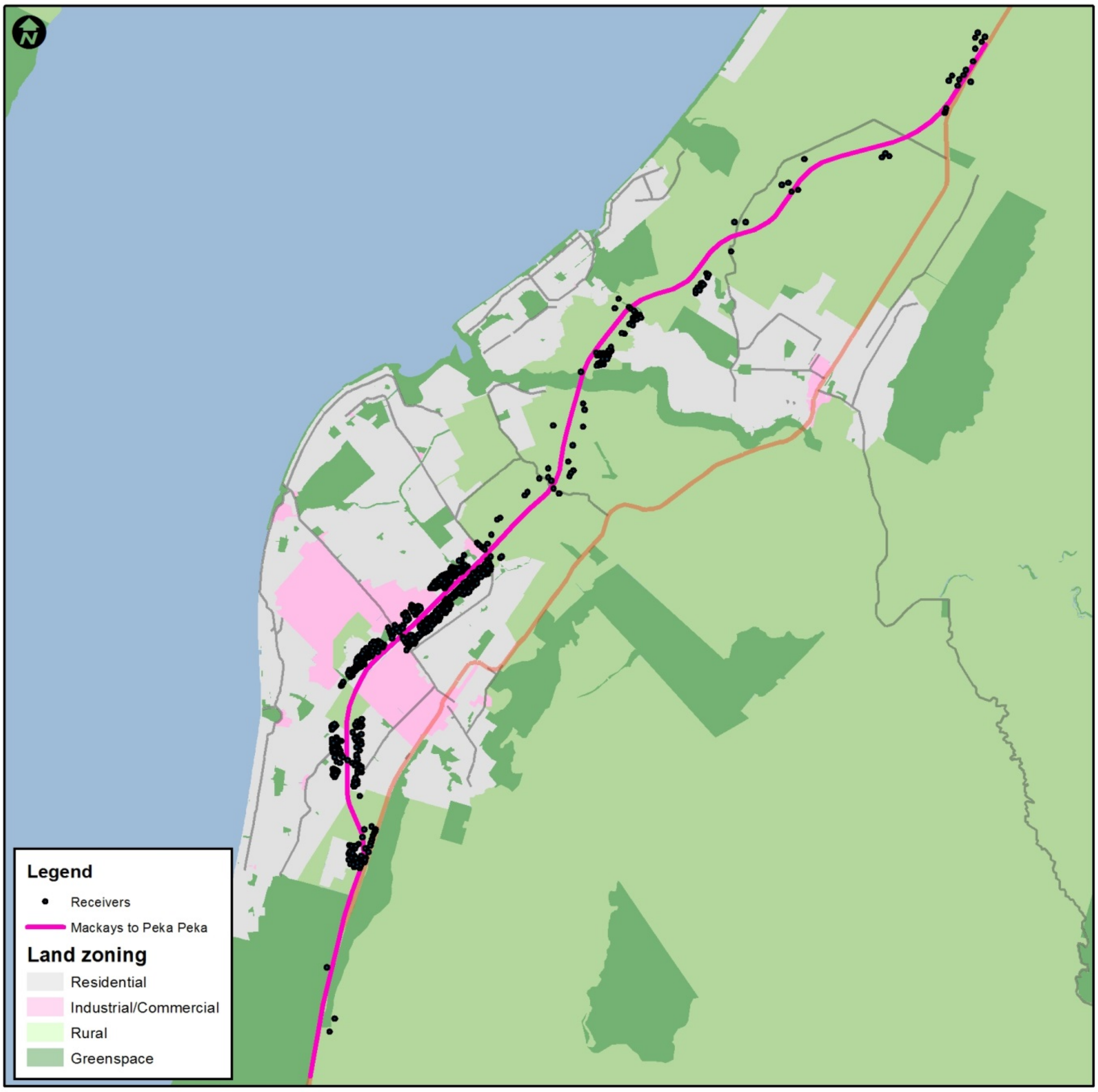
The Cambridge bypass forms an integral part of the Waikato Expressway, which will link Auckland to Waikato and the Bay of Plenty. The Cambridge bypass is a 16 km section of new roads, much of which pass through sparsely populated rural land. The number of potential receivers near to the alignment is low, except for a 2 km section north-east of Cambridge where the alignment passes near to a residential area.

Figure 3.3 Waikato – Cambridge bypass

3.1.5 Wellington Northern Corridor – Mackays to Peka Peka

Mackays to Peka Peka is an 18 km expressway that provides a key link in the new Wellington Northern Corridor. The expressway passes through a mixture of residential and rural land, resulting in a varied existing noise environment. There are some grade separated interchanges and underpasses at the southern end where the alignment passes through a residential area.

Figure 3.4 Mackays to Peka Peka



3.1.6 Site selection

While four of the RoNS sites have been identified as potentially suitable locations for before and after surveys as part of the community response research, sampling requirements dictate that the chosen study area has a sufficient number of receivers to ensure a statistically reliable population. From the data in table 3.5 only the Auckland Western Ring and Mackays to Peka Peka routes have sufficient receiver numbers. Both projects have approximately the same proportion of residential receivers (zoning). However the Auckland study area does have a high number of receivers within 100 m from the road compared with Mackays to Peka Peka and therefore the surrounding receivers are likely to experience a greater variance in road traffic noise level, which is considered important when establishing a reliable dose-response relationship.

The only detractor is that the Western ring project has existing exposure to sources of road traffic noise, whereas Mackays to Peka Peka passes through a mixture of residential and rural land with some major existing roads at the southern end where the alignment passes through a residential area. The questionnaire would therefore have to consider existing sources of road traffic noise and the combination of noise from all roads post opening. Based on sampling numbers alone, the Auckland Western Ring project was selected as the preferred RoNS project.

It is recognised that with any new scheme the local community may be sensitised to the future change in road traffic noise level either as a result of construction activities or a dissatisfaction that arose during the 'consenting process'. To limit these potential sensitivities, the study's questionnaire included commentary on 'other noise' such as existing construction noise and also gave the respondent an opportunity to comment on other factors.

3.1.7 Study areas

The three selected study areas were:

- existing road – Auckland SH 1
- new or altered road – Auckland Waterview Connection[6]
- rail – Auckland southern rail corridor

3.2 Noise levels

Noise levels from road and rail traffic, where applicable, were calculated within the areas defined along each of the study's road and rail routes. This was done with CadnaA noise modelling software and information available from Auckland Transport, Kiwirail (freight movements) and the Transport Agency. The road noise modelling techniques used are well established in New Zealand, and consistent with the Transport Agency's (2013) *Guide to state highway noise mapping*. The rail noise modelling was similar to the road traffic noise modelling procedure, see table 3.6.

Traffic data has been provided for all roads as the annual average daily traffic (AADT), percentage of heavy vehicles and speed. This has been provided separately for each carriageway. The calculation of road traffic noise (CRTN) model (UK Department of Transport 1988) has been developed based on traffic flows conditions within an 18-hour period from 6 am to midnight. For New Zealand conditions traffic flows have been entered as the 24-hour AADT, which results in modelling in the order of +0.2 dB conservative. Surfaces of existing roads have been modelled as the current surfaces recorded in the RAMM as viewable in MobileRoad[7]. As the CRTN algorithm gives results in terms of the $L_{A10(18h)}$, a -3 dB adjustment is required to obtain the $L_{Aeq(24h)}$. This adjustment has been implemented in the software in conjunction with the road surface adjustment.

The rail modelling used rail timetable information and comparable source level information for the passenger trains (AM class electric multiple units) and the freight trains (DC, DF and DL class locomotives).

[6] Before stage only – prior to road opening

[7] https://mobileroad.org/

The calculation of rail noise (CRN) (UK Department of Transport 1995) algorithm calculated $L_{Aeq\ (18h)}$ data which was then corrected to 24-hours using a -1dB correction. This adjustment was implemented in the software.

For each study area $L_{Aeq\ (24h)}$ noise levels were calculated at each residential address point and the diurnal pattern of noise levels across an 'average' day was calculated outside the noise model based on the distribution of recorded hourly flows obtained from Auckland Transport and the summer 2016 passenger and indicative freight timetables.

Table 3.6 Cadna/A assessment parameters

Parameter	Setting/source
Software	Cadna/A 2016
Algorithm	CRTN – road, CRN – rail
Reflection model	CRTN – road, CRN – rail
Parameter L_{Aeq}(24h)	Terrain contour resolution 0.5m Auckland Council
Ground absorption	1.0
Receiver height	1.5 m (4.5 m upper floors) – most exposed façade
Receivers and grid position	free-field

4 Survey design

4.1 Sample selection

Respondents were defined as residents living in the area of the study sites who were 18 years of age and over. To select these respondents, the New Zealand General and Māori Electoral Rolls were used, as they are the most comprehensive and up-to-date registers of New Zealanders aged 18 years and over. Access to the electoral rolls was granted through a formal application process via the Electoral Commission's Enrolment Services. This information included electors address details which were used to confirm they lived within each of the three study sites. This sample of Auckland electors was then sent to DataZoo, one of New Zealand's key list providers. DataZoo narrowed the sample down to households in specific streets identified as being within the three study areas. DataZoo then telematched the sample in order to obtain contact land-line telephone numbers (as phone number details are not contained in the electoral rolls). Telematching was completed by data matching the names and addresses from the electoral roll sample, against listings from Land Information New Zealand (LINZ), the NZ Companies Office, Transport Agency and the Department of Internal Affairs. All matched phone numbers were then verified by yellow against current white page listings.

The telematched sample was then further refined to a more precise list of eligible households within the study areas based on the modelled levels of traffic noise (road and/or rail) at each address location. For some address points multiple noise levels were calculated due to the presence of separate buildings, which were assumed by the modelling process to be individual properties. The information provided in relation to these properties was further screened based on a cross check of address location with aerial mapping data to confirm the correct noise rating and in some cases, the correct address.

The noise level data was divided into three equal groupings to represent low, medium and high decibel ratings for each of the three study site areas. In all cases the noise groupings are relatively low in comparison to typical noise levels encountered near road and rail corridors. Where possible, the final samples were stratified across the three groups to ensure a proportionate number of interviews were completed for each noise level grouping and thereby result in an even distribution of survey responses across the entire noise level range. The noise level groupings for each study site are presented in table 4.1.

Table 4.1 Noise level groupings ratings for the three study sites

Noise level band	$L_{Aeq\ (24h)}$ / dB		
	SH1	Waterview	Rail
Low	<48.5	<46.0	<44.5
Medium	48.5–53.0	46.0–50.3	44.5–50.3
High	>53.0	>50.3	>50.3

4.2 Survey development

The survey questionnaire conformed to ISO/TS 15666: 2003 and was reviewed by the Steering Group. A few minor additions were added to help provide contextual information about when (ie the days and times) respondents are likely to be at home and therefore when they are likely to be exposed to local road and rail traffic noise. Despite these minor additions, the survey questionnaire was not cognitively pretested because it fundamentally conformed to the structure of the ISO questionnaire format. The length of the questionnaire was limited by the need to keep the completion time to approximately 10–15 minutes.

When the questionnaire was finalised, Research New Zealand's Survey Scripting Team initially scripted the survey instrument for administration as a computer assisted telephone interviewing (CATI) survey and then later as an online survey tool. As part of this process, the researchers responsible for the project and the Survey Scripting Team worked closely together in order to test and double-check the internal (technical) integrity of both versions of the questionnaire.

The questionnaire was structured as follows:

- Introduction – including background information on the questionnaire
- Demographic details – including age, ethnic group, employment and residential status
- Source of noise and disturbance – based on a five-point scale
- Impact of noise from road traffic – ISO 11 point scale and times of day when at home
- Impact of noise from rail traffic – ISO 11 point scale and times of day when at home
- Transport usage – forms of transport the respondent uses
- Recruiting for second household interview
- Closing questions – opportunity to make comments

A copy of the final questionnaire can be found in appendix B to this report.

4.3 Interviewing process

A staggered approach to the interviewing was required for this research, timed around the availability of noise level ratings for the eligible households within each of the three study site areas and to not coincide with periods when potential respondents were not at home (ie outside the summer holiday period of 2016/2017).

The first study area for which noise level data was made available, was SH 1 south. At the end of September 2016, pre-notification letters were posted to a random selection of households in the study site area for whom telephone numbers and noise level ratings were available. The letter was mailed on Research New Zealand letterhead and, in accordance with the Code of Practice of the Research Association of New Zealand Incorporated (Research Association New Zealand 2015), introduced the research, explained how their household had been selected and what participation in the research involved. The letter also explained that their participation was voluntary, but should they agree to participate, any information would be treated in the strictest confidence and only be reported in an aggregated form as statistics. The Research New Zealand 0800 freephone number was also provided if any prospective respondents required any additional information.

Approximately one week after the letter was posted, respondents were contacted by telephone and asked if they would like to complete the survey. All telephone interviewing was completed from Research New Zealand's CATI-enabled call centre in central Wellington.

The researchers responsible for the project personally briefed the team of interviewers assigned to this project, prior to the survey commencing. As well as providing some background information with regard to the purpose of the research and how respondents had been selected to take part, the briefing also involved a discussion with the interviewers about the specific survey questions.

The first few days of interviewing were treated as a pilot, with the survey data extracted and checked to ensure the survey script was working as intended and there were no issues from a respondent or an interviewer perspective. As no issues were found, the interviewing then recommenced, although data checks continued to occur periodically.

Up to five attempts were made to contact each household, on different days and at different times. If an interview was not secured after five attempts, that phone number was replaced with the phone number for the next household on the list. Interviews were completed on both land lines and mobile phones, with respondents able to schedule appointments in order to complete their interview at a more convenient time. Numbers permitting, the ideal target per study area was n=400 interviews. By 1 November 2016, the target of n=400 telephone interviews had been achieved within the SH 1 study area.

A similar survey process was followed for the Waterview and rail study areas, with their pre-notification letters posted in October 2016 and March 2017 respectively. However, there was a limited sample available for these two latter areas. With only 171 phone numbers available for the eligible properties in Waterview, and 657 for the rail area, an alternative approach was introduced in order to maximise the response, and augment the telephone interviewing. A ‘snowball’ approach was also attempted within these two study site areas, resulting in an additional n=8 completed interviews[8].

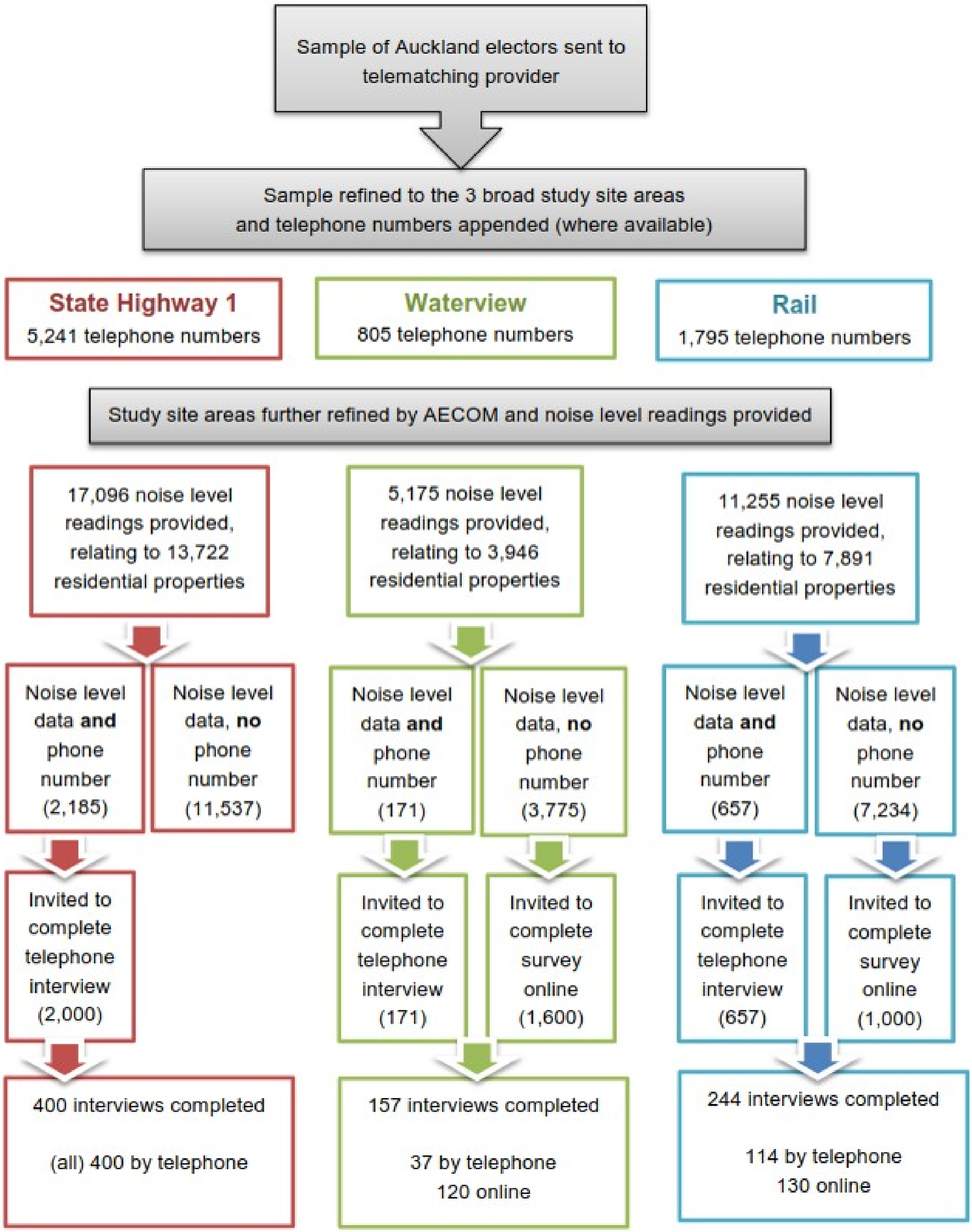
When all the available telematched samples for the Waterview and rail study site areas had been exhausted, an online version of the survey was scripted. In April 2017, pre-notification letters were posted to households in those two study site areas for whom noise level data was available, but no telephone numbers. This letter invited respondents to complete the survey online, or to contact Research New Zealand if they wanted to do the survey by telephone. A copy of this letter is included in appendix C. To further encourage response, Waterview and rail respondents were also offered the chance to go into a prize draw for one of three grocery vouchers worth $150 each. By 30 April 2017, n=157 interviews were completed for the Waterview study site area and n=244 completed for the rail study site area.

The average interview length across all three study site areas was 13.4 minutes.

Figure 4.1 summarises the sampling and interviewing process.

[8] ‘Snowballing’ involves recruiting a second respondent from within the same household to complete the survey.

Figure 4.1 Field process



4.4 Quality assurance processes and standards

Research New Zealand has been accredited with the industry-wide Interviewer Quality Standards (IQS) for the last 14 consecutive years[9]. In general, the company's interviewers undergo extensive training (both

[9] IQS is the Research Association of New Zealand's quality standard for call centres. This is independently audited each year

initially and on an on-going basis), and are supervised, beyond the minimum IQS-standards. Research New Zealand's Quality Assessors verified a minimum of 10% of each telephone interviewers' work by intercepting their calls. In addition, a random selection of interview recordings was observed to validate that interviewers had correctly coded responses to a minimum of five questions.

After the first and second day's telephone interviewing was completed in relation to each study site area, the data was extracted and examined by the researcher responsible for this project to confirm the routing was working as intended, to check the quality of the verbatim comments being recorded and to check if the interviewers had recorded any concerns or notes at the end of the survey. This process was repeated periodically thereafter, until the fieldwork concluded. As is standard practice, all interviews were recorded to provide an additional level of quality control.

The online interviewing was hosted on the Research New Zealand secure computer site. In order to prepare the online version of the survey questionnaire, the Survey Scripting Team and the researcher responsible for this project completed comprehensive testing of the scripted online questionnaire before it was launched.

5 Data analysis

Each study area was analysed both individually and combined. The initial analysis concentrated on the demographics of the sample and considered the statistical adequacy of the sampled population. The data was then analysed in terms of the annoyance scores for different sources of noise and the percentage highly annoyed for road and rail. Comparison with other noise sources surveyed was undertaken.

5.1 Demographics

The ratio of women to men was approximately 60:40 (figure 5.1) and the age distribution is shown in figure 5.2. The Auckland age distribution obtained from the 2013 census data is also overlaid. The data shows that the sample for each study area has a greater proportion of older respondents compared with the general population and the sample has fewer respondents compared with the general population in the age range 18–24.

Figure 5.1 Percentage distribution of gender of surveyed individuals

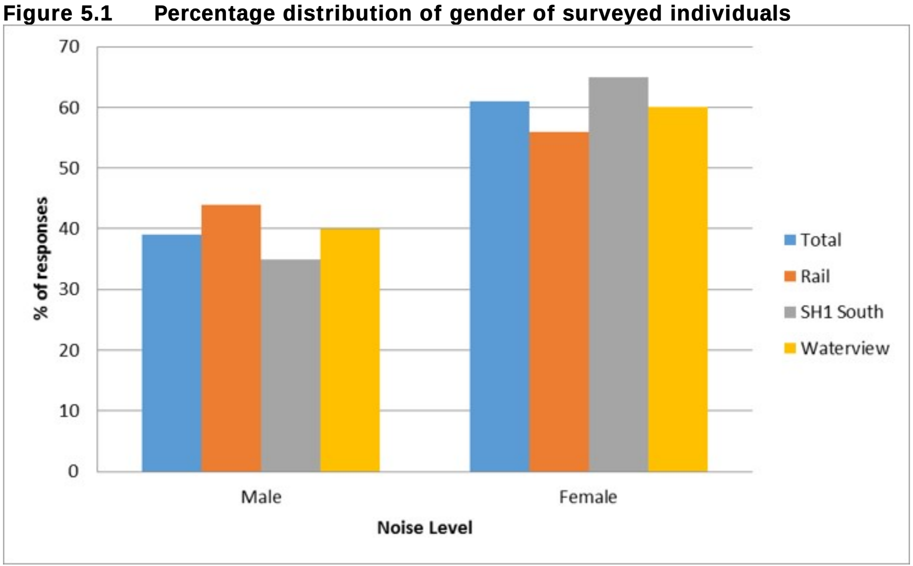
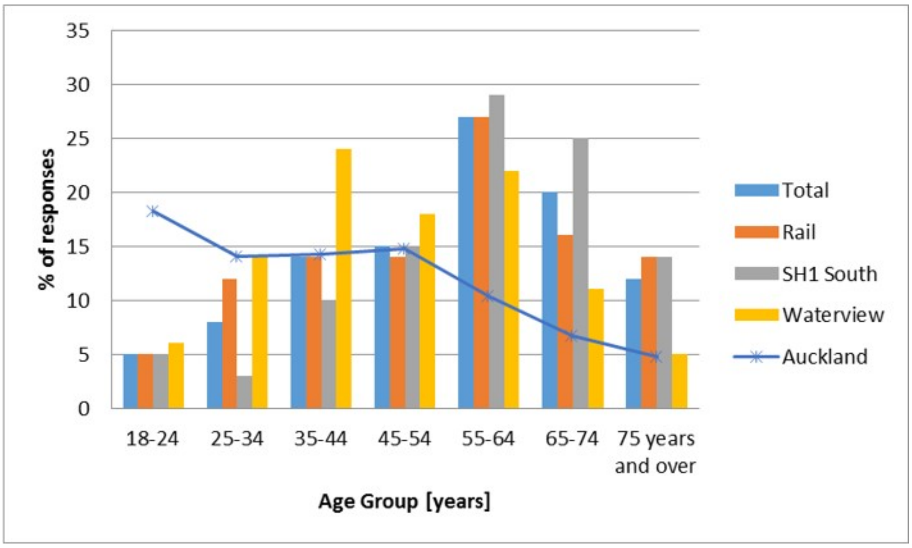


Figure 5.2 Percentage distribution of age of surveyed individuals including Auckland 2013 Census data



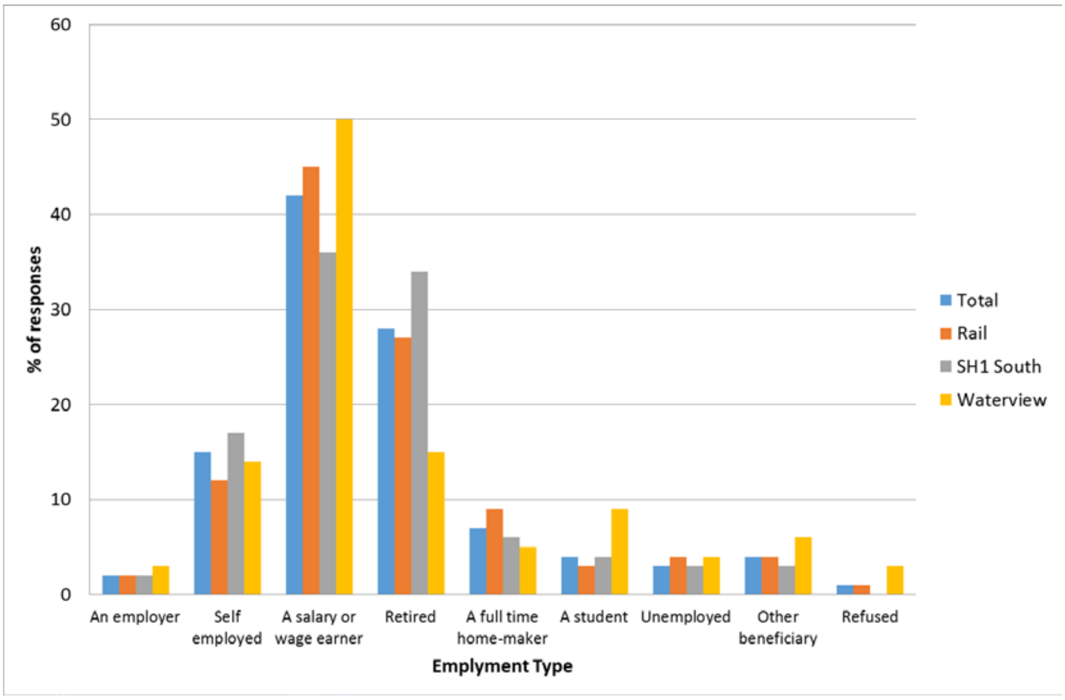
The ethnicity of each study area and across all three areas is shown in table 5.1. The table also includes Auckland population data from the 2013 census.

Table 5.1 Ethnicity of respondents

Ethnicity	Total	Rail	SH1 South	Waterview	Auckland Census
	%	%	%	%	%
New Zealand European (or Pakeha)	69	66	77	53	56
Māori	9	14	7	8	10
Samoan	3	4	2	6	7
Cook Island Māori	1	1	1	1	3
Another Pacific nation (Tongan, Niuean, Tokelauan, Fijian)	6	6	5	8	6
Chinese	4	2	2	9	22
Indian	7	8	5	10	7
Other	8	8	8	12	10
Refused	1	1	0	1	n/a

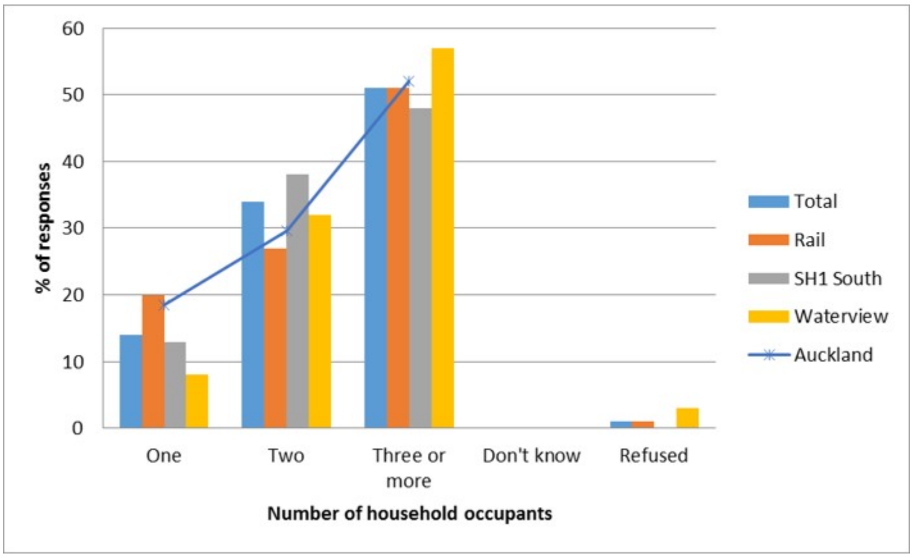
The employment status of the sample is presented in figure 5.3. Compared with the Auckland 2013 Census data the sample across each study area has a greater proportion of retired individuals and a lower number of individuals in employment (sampled 42% against 78% for the Auckland population in 2013). This is partly reflected by the age distribution shown in figure 5.2.

Figure 5.3 Employment status



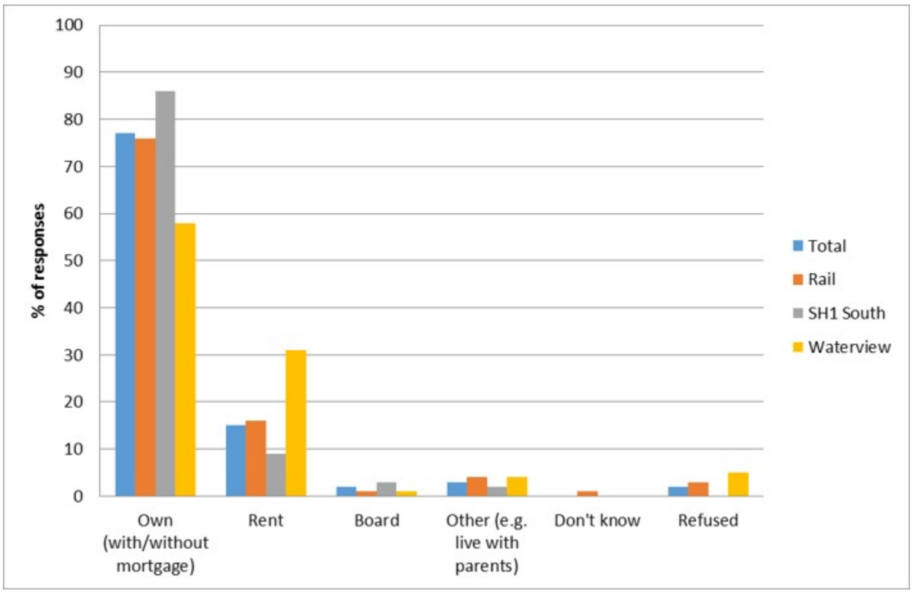
The number of occupants per household is reported in figure 5.4 and follows a similar pattern to the 2013 census data for Auckland.

Figure 5.4 Number of occupants in household



The tenure of the each respondent's household within the study areas is shown in figure 5.5. The 2013 Census data for the Auckland region indicates that home ownership (with/without mortgage) is 43% which is 4% below the national level and rented properties account for 36% of the market. The study areas show a greater bias towards home ownership rather than rented when compared with national and regional levels. Only the Waterview study area is comparable to the Auckland average.

Figure 5.5 Home ownership



The study areas show a greater proportion of older respondents compared with the Auckland population and a consequence greater number of retired individuals.

Figure 5.6 shows the proportion of motor vehicle ownership among the respondents and figure 5.7 shows the modes of transport used. There is a heavy reliance on car usage among each of the study areas.

Figure 5.6 Motor vehicle ownership

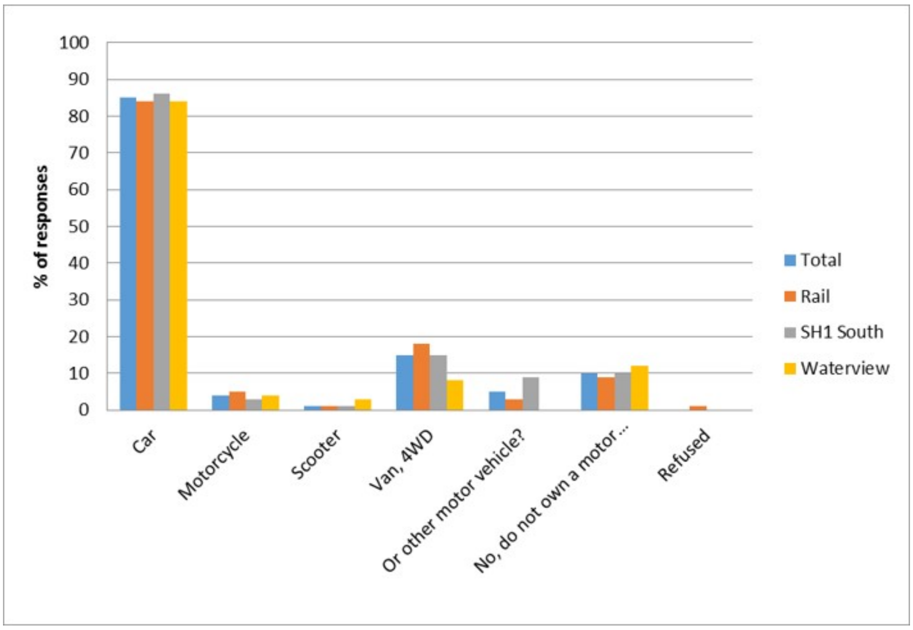
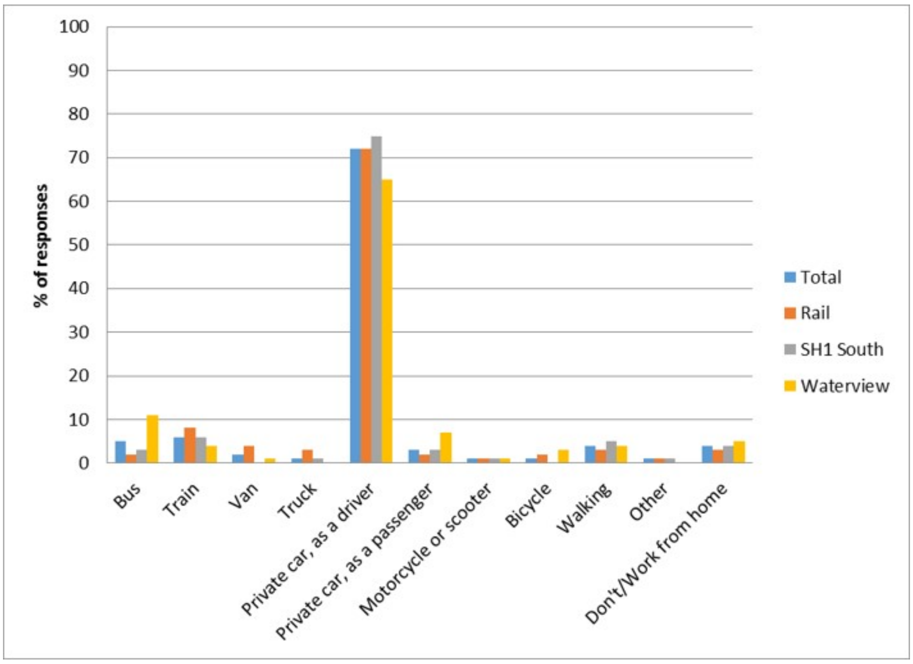


Figure 5.7 Form of transport used to travel the greatest distance



5.1.1 Representation

The demographics of the sampled population show a greater tendency to a more aged sample compared with the Auckland average (as obtained from the 2013 Census results) and that home ownership is also above the Auckland average. Hypothesising this may be partly due to the fact that respondents were more likely to be home when the interviews were conducted and there might be a greater likelihood of these respondents having a land line rather than solely a mobile phone, which was the primary means of contacting respondents.

On the basis that there are no cited studies which have considered whether there is a material difference in the annoyance response of different age groups, this study's sample is considered representative of the wider population within margins of error as reported in section 5.2.

5.2 Confidence intervals

The results based on the total sample of n=801 respondents are subject to a maximum margin of error of ±3.5 % at the 95th percentage confidence level. This means, for example, that if 50% of respondents reported being affected by road traffic noise, there would be a 95% confidence of getting the same result, plus or minus 3.5%, had all eligible households been interviewed within the three study areas. Higher margins of error apply to each of the three individual study site areas based on the achieved sub-sample sizes.

Table 5.2 shows the number of interviews completed for each study site, along with the associated maximum margins of error.

Table 5.2 Maximum margins of error (at the 95% confidence level)

	SH1	Waterview	Rail	Total
Total interviews completed	400	157	244	801
Maximum margin of error	±4.9%	±7.8%	±6.3%	±3.5%

The ideal margin of error in terms of reporting is less than 5%. However, for small sample sizes the next target is to achieve a margin of error less than 10%.

These margins of error have been applied to the dose-response assessment.

5.3 Noise annoyance dataset

The percentage distribution of respondents within each noise level grouping (as defined in table 4.1) is provided in table 5.3 and within each noise band the predicted range of road or rail traffic noise levels is shown in table 5.4.

Table 5.3 Noise level grouping

Noise level band	Total	Rail	SH 1 south	Waterview
	%	%	%	%
Low	39	22	48	41
Medium	26	39	16	30
High	35	39	35	29

Table 5.4 Noise level ranges within study areas

Noise level band	$L_{Aeq(24h)}$ dB		
	Rail	SH 1 south	Waterview
Low	35–43	40–49	32–46
Medium	45–50	49–53	46–50
High	50–64	53–72	50–64

For the purposes of the noise dose and annoyance response assessment the modelled levels of noise, expressed as $L_{Aeq\ (24h)}$, were rounded up to the nearest whole decibel. Although there will always be a degree of uncertainty associated with noise modelling, which can typically vary around 1–3 dB, no margins of error were applied to the data set as it was considered that any uncertainty would apply equally across all calculated address points.

As decibels are a logarithmic measure of the sound pressure, a sound pressure level change in the order of 1–3 dB is often described as imperceptible change in sound when subjectively assessed. Differences in the order of 5 dB or greater would be clearly perceptible. A difference in sound level of around 10 dB would be classed as either doubling or halving the perceived loudness.

5.3.1 Reported annoyance

The following tables summarise the number and percentage of respondents for each study area who rated the noise of the 10 sources of environmental noise using the five-point annoyance scale of ‘not annoyed’, ‘slightly annoyed’, ‘moderately annoyed’, ‘very annoyed’ and ‘extremely annoyed’. The scale has been grouped according to the ratings of ‘slightly’ to ‘extremely’, ‘moderately’ to ‘extremely’ and ‘very’ to ‘extremely’.

Table 5.5 Rail study area – reported annoyance

Source of noise (n=244)	Proportion of respondents bothered, annoyed or disturbed by noise source (%)		
	Slightly to extremely	Moderately to extremely	Very to extremely
Aircraft	61	36	21
Alarms or sirens	66	40	22
Animals	56	33	15
Buildings and construction	48	24	10
Local businesses, factories or industry	32	15	9
Pubs and nightclubs	21	6	4
Neighbours, including their children	64	37	21
Road traffic	70	50	30
Road works	45	23	14
Trains	61	36	19

Table 5.6 SH 1 study area – reported annoyance

Source of noise (n=400)	Proportion of respondents bothered, annoyed or disturbed by noise source (%)		
	Slightly to extremely	Moderately to extremely	Very to extremely
Aircraft	45	21	6
Alarms or sirens	49	21	7
Animals	42	19	6
Buildings and construction	29	14	4
Local businesses, factories or industry	13	7	4
Pubs and nightclubs	5	3	1
Neighbours, including their children	39	19	8

Source of noise (n=400)	Proportion of respondents bothered, annoyed or disturbed by noise source (%)		
	Slightly to extremely	Moderately to extremely	Very to extremely
Road traffic	69	46	24
Road works	41	20	6
Trains	19	6	1

Table 5.7 Waterview study area – reported annoyance

Source of noise (n=157)	Proportion of respondents bothered, annoyed or disturbed by noise source (%)		
	Slightly to extremely	Moderately to extremely	Very to extremely
Aircraft	54	22	9
Alarms or sirens	74	43	25
Animals	53	29	13
Buildings and construction	65	48	25
Local businesses, factories or industry	26	9	3
Pubs and nightclubs	19	6	4
Neighbours, including their children	69	46	25
Road traffic	81	62	37
Road works	63	42	25
Trains	26	10	5

The rail study area reported a greater annoyance to rail traffic than both the road study areas. 19% of the sample reported high annoyance to trains, whereas the other areas reported 1% and 5% respectively for SH 1 and Waterview (even though there are no rail lines within the study areas). The most dominant source in terms of reported annoyance for each study area was road traffic noise, with Waterview achieving the highest score of 37%[10]. In comparison to the other study areas, SH 1 on average has a lower occurrence of high annoyance. Excluding road traffic, the aggregate annoyance score for SH 1 was calculated to be 5%, whereas the other two study areas have an average high annoyance score of 15%. Certain elements of the Waterview study area (see figure 3.2) have been subject to extended periods of construction works, and the respondents rated 'building and construction' and 'road works' higher in comparison to the other two study areas.

[10] This rating was prior to the opening of the state highway and may be subjected to a degree of noise sensitivity due to the impending change in the local noise environment once the construction works were completed and the road open for traffic.

Table 5.8 Study area – reported annoyance

Source of noise	Proportion of respondents 'very' to 'extremely' bothered, annoyed or disturbed by noise source (%)		
	Rail	SH1	Waterview
Aircraft	21	6	9
Alarms or sirens	22	7	25
Animals	15	6	13
Buildings and construction	10	4	25
Local businesses, factories or industry	9	4	3
Pubs and nightclubs	4	1	4
Neighbours, including their children	21	8	25
Road traffic	30	24	37
Road works	14	6	25
Trains	19	1	5

5.3.2 Percentage highly annoyed

Schultz (1978) developed a relationship between the percentage of people choosing the top two descriptors ('very annoyed' and 'extremely annoyed', which are combined within the term 'highly annoyed') and residential noise exposure. Schultz defined 'highly annoyed' respondents as those respondents whose self-described annoyance fell within the upper 28% of the response scale. It is common practice to convert the (average) annoyance scores on the verbal and numerical to a 0–100 point scale. The response may also be expressed as the percentage highly annoyed (%HA), which is the percentage of people giving an answer above 72 (the top 27–29%) of the response scale, ie the verbal categories 'very', 'extremely', and the numerical categories 8, 9 and 10.

The following graphs show the relationship between the %HA as a function of $L_{Aeq\ (24h)}$ for each study area for the rail and road traffic study areas. The rail study area only considers the noise contribution from rail traffic and not the cumulative effects of other sources of environmental noise, specifically from road traffic. The solid element of each line shows the noise exposure of the sample population and the dash line shows the extrapolation to 70 dB $L_{Aeq(24h)}$ (none of the surveyed locations experienced predicted noise levels greater than this level).

Figure 5.8 Rail study area (rail traffic) – percentage highly annoyed (%HA) as a function of $L_{Aeq(24\ h)}$

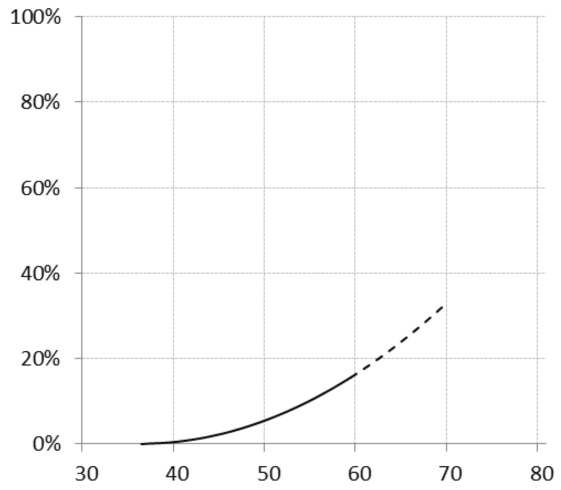


Figure 5.9 SH 1 (road traffic) – percentage highly annoyed (%HA) as a function of $L_{Aeq(24\ h)}$

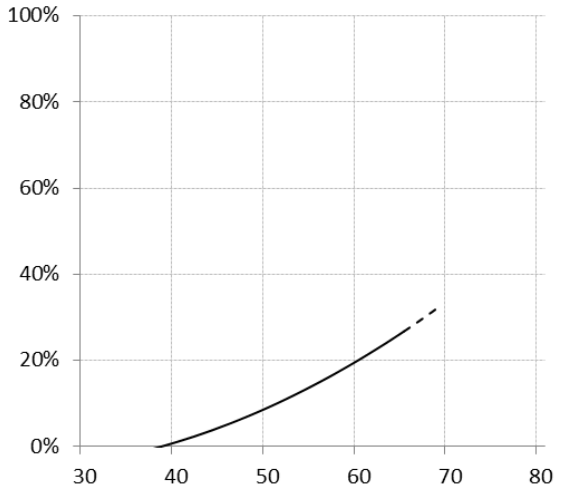
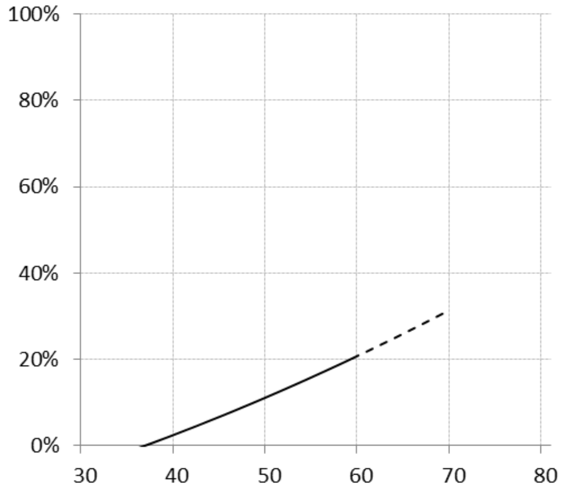


Figure 5.10 Waterview (road traffic) – percentage highly annoyed (%HA) as a function of $L_{Aeq(24\ h)}$



Within the approximate range 40–65 dB, the dose response relationships are considered acceptable. Outside this range (dotted lines) the relationships are not useable.

The Miedema and Vos (1998) standardised dose-response curves are expressed as day/night levels (DNL or L_{dn}). The L_{dn} is a measure with a night time penalty of 10 dB calculated from the L_{Aeq} for the daytime and L_{Aeq} for the night-time. At a given exposure level, aircraft noise causes the highest %HA, followed by road traffic and rail traffic, respectively.

When comparing the %HA versus noise level for each study area and noise source, the rail study area has the highest %HA at 62 dB $L_{Aeq(24h)}$ (20%HA, figure 5.8), compared with 59 and 58 dB $L_{Aeq(24h)}$ for SH 1 (figure 5.9) and Waterview (figure 5.10) respectively. These findings agree with those of Miedema and Vos (1998).

The two road study areas have different noise characteristics. SH 1 is an existing and well established noise environment and while a proportion of the population is not annoyed by road traffic noise, a significant number of respondents were highly annoyed. The Waterview study area is subjected to a mix of road traffic noise from both local roads and nearby motorways, as well as construction noise. The dose response for both roads is comparable but does differ.

Miedema and Vos (1998) demonstrated that differences between the dose-response curves may be caused by acoustical as well as non-acoustical factors for the different modes of transport and that the exposure to noise from a single source by an individual at home is complex and varies over time, and between places in and around the dwelling.

The Miedema and Vos meta-analysis dose-response curves follow the equations:

$$Road\ traffic\colon\quad \%HA = 0.24(DNL - 42) + 0.0277(DNL - 42)^2$$

$$Rail\colon\quad \%HA = 0.28(DNL - 42) + 0.0085(DNL - 42)^2$$

These equations are applicable for a range of noise levels from L_{dn} 45–75 dB.

In comparison with the meta analyses of Miedema and Vos (figure 2.1) and after adjustment of the L_{dn} (DNL) exposure levels to $L_{Aeq(24h)}$, there is a mean increase between the L_{dn} and $L_{Aeq(24h)}$ values of 1.5dB across the noise exposure range (L_{dn} values being higher than the equivalent L_{Aeq}).

The outcomes of the annoyance assessment, when correcting for noise metric and taking into account the margins of error associated with each study area, follows a similar pattern of increasing annoyance with noise level when compared with the datasets reported by Miedema and Vos (as obtained from an original database of studies compiled by TNO (The Netherlands Organisation for Applied Scientific Research) in Leiden).

Figures 5.11 through 5.13 present the Miedema and Vos meta-analysis dose-response curves along with best fit regression dose-response curves derived from this study.

Figure 5.11 shows that the rail study area has a higher reported annoyance rating when compared with the meta-analysis of TNO. The onset of annoyance occurs at a lower noise level.

In comparison to the meta-analysis, the study’s reported annoyance scores are greater for the two road study areas, see figures 5.12 and 5.13.

Figure 5.11 Rail study area (rail traffic) – percentage highly annoyed (%HA) as a function of L_{dn}

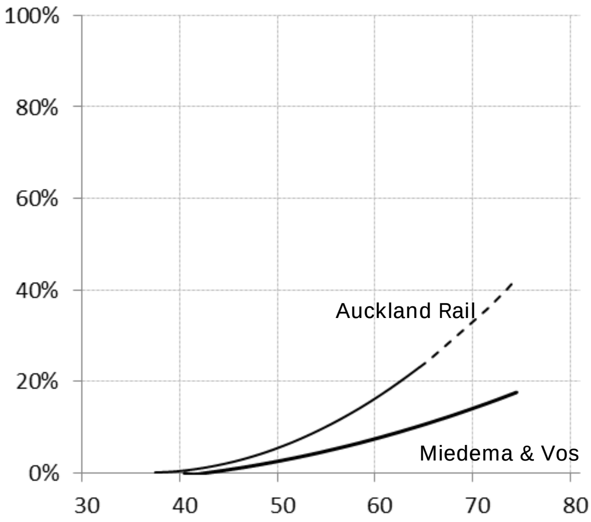


Figure 5.12 SH 1 (road traffic) – percentage highly annoyed (%HA) as a function of L_{dn}

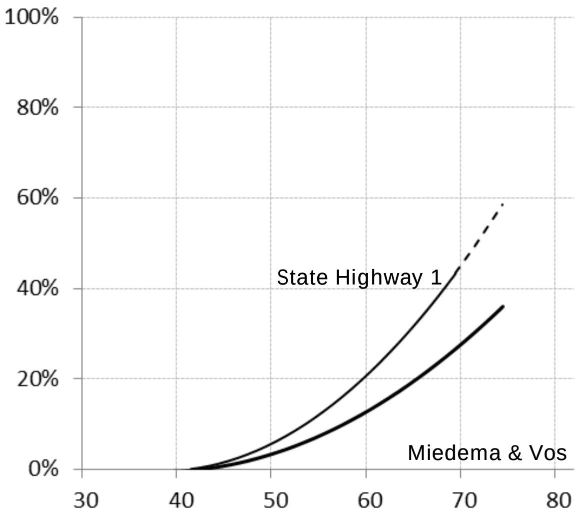
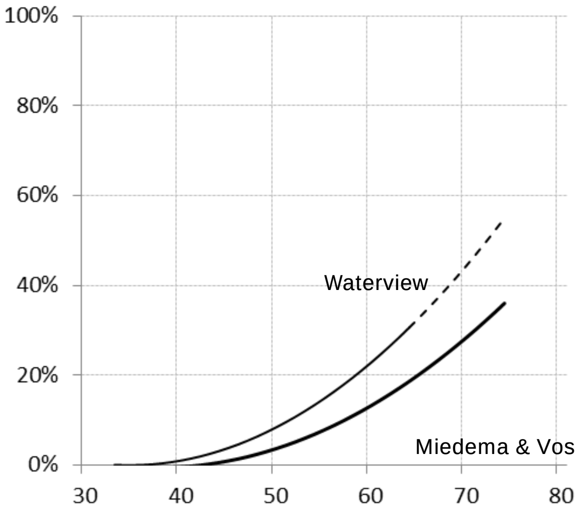


Figure 5.13 Waterview (road traffic) – percentage highly annoyed (%HA) as a function of L_{dn}



The onset noise levels for each study area and noise metric are shown in table 5.9. Below 0 %HA, there is no reported annoyance, while significant reported annoyance occurs above 20 %HA. It should be remembered that the reported noise levels are predicted levels only and do not necessarily include noise from all sources of environmental noise.

Table 5.9 Onset noise levels for high annoyance

	Study area	$L_{Aeq(24h)}$ / dB	L_{dn} / dB	Miedema and Vos
>0 %HA	Rail	37	40	42
	SH 1	40	42	42
	Waterview	38	39	42
>20 %HA	Rail	62	63	76
	SH 1	59	60	65
	Waterview	58	59	65

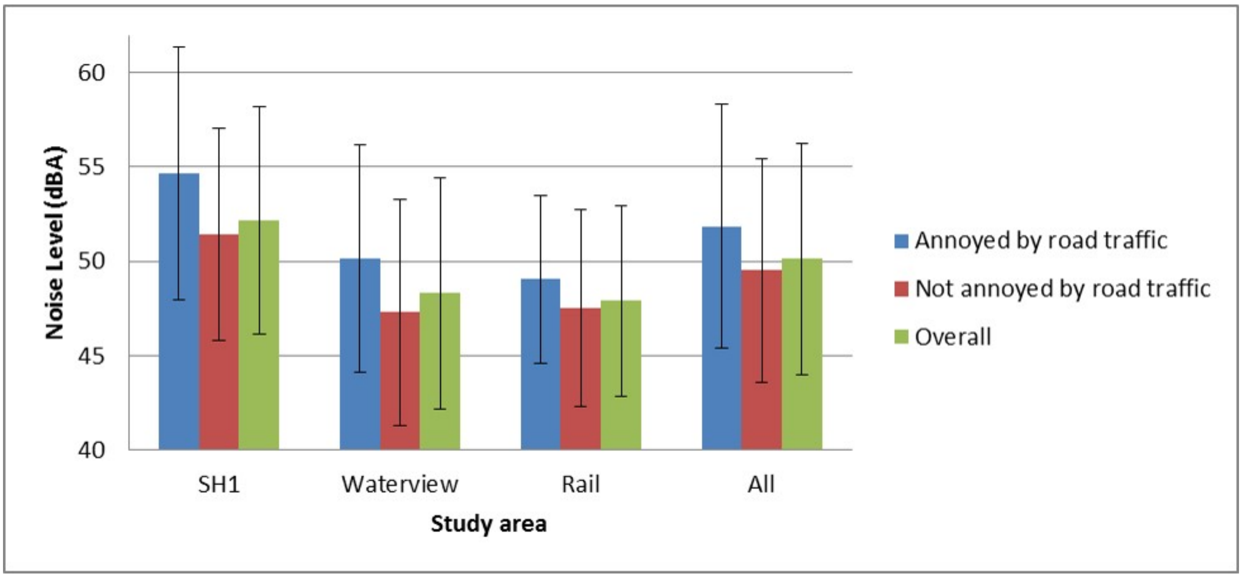
After adjustment of the study's $L_{Aeq(24h)}$ to L_{dn}, New Zealand's onset of community annoyance (0 %HA) occurs at a similar sound level to that found by Miedema and Vos. Significant community response in the three study areas was found to occur at lower sound levels when compared with Miedema and Vos. This would suggest the New Zealand population is more sensitive to noise as the onset occurs at lower sound levels (approximately 13 dB lower for rail and 6 dB lower for road than the Miedema and Vos response curves).

Although the principal objective of the study, which was to compare community response to short-term changes in noise compared with existing steady-state conditions, was not fulfilled, it is recommended that future studies should aggregate the results from a number of sites to increase the population size and hence statistical confidence of the results. In the short term, an assessment of the following four roads of national significance is recommended:

- Auckland Western Ring Route
- Waikato Expressway – SH 1
- Wellington Northern Corridor
- Christchurch Motorways

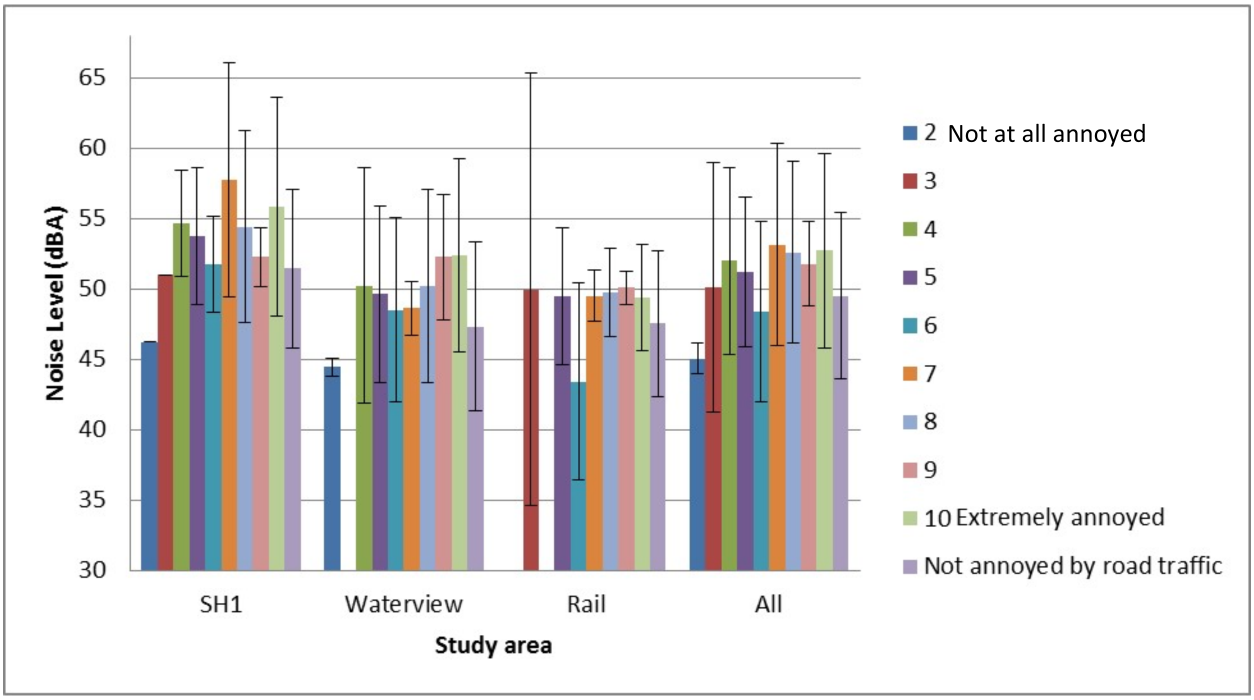
The statistical significance of the dataset was tested using the ISO/TS 15666 11 point scale question.

Figure 5.14 Mean noise levels for 'annoyed' and 'not annoyed' individuals for different areas and combined dataset



Note: Error bars showing standard deviation of dataset

Figure 5.15 Mean noise level for different annoyance levels reported by 'annoyed' individuals for different areas and overall dataset



Note: Error bars showing standard deviation of dataset

As can be seen in figure 5.14 there is a difference in the mean noise levels for the 'annoyed' and 'not annoyed' individuals. To confirm this a T-test was performed. This assumed normally distributed data with relatively similar variances. An alpha value of 0.05 was used thus indicating a 95% confidence levels in the test result.

The results of the T-test can be seen in table 5.10. This shows that a statistically significant difference was present in the mean noise levels for 'annoyed' and 'not annoyed' individuals due to land based transportation noise.

Table 5.10 Statistical significance of dataset

Description		SH 1	Waterview	Rail
Mean noise levels (dB)	Annoyed by traffic	55	50	48
	Not annoyed by traffic	51	47	48
T-test (p value)		0.00005	0.005	0.03
Alpha		0.05	0.05	0.05
p<Alpha, if so, statistically significant difference.		TRUE	TRUE	TRUE

As well as a T-test, box plots were also generated for the surveyed areas and overall dataset. These can be seen below in figures 5.16 to 5.18. These can be used in combination with the T-test result and figure 5.15 to support the statistically significant difference between 'annoyed' and 'not annoyed' individuals.

Figure 5.16 Rail box plot

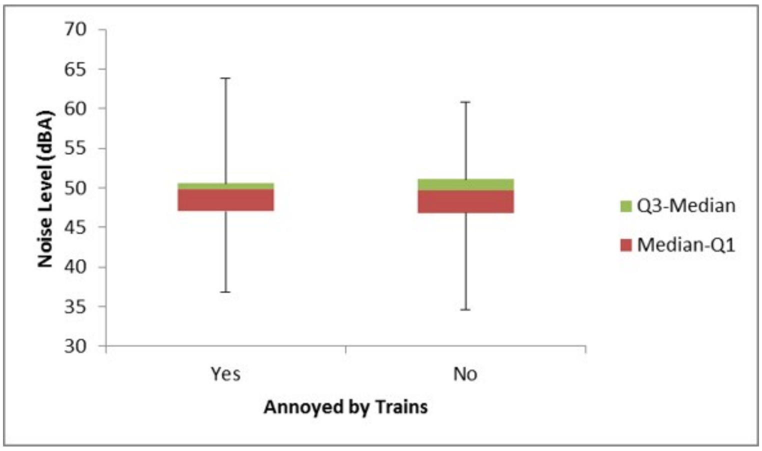


Figure 5.17 SH 1 box plot

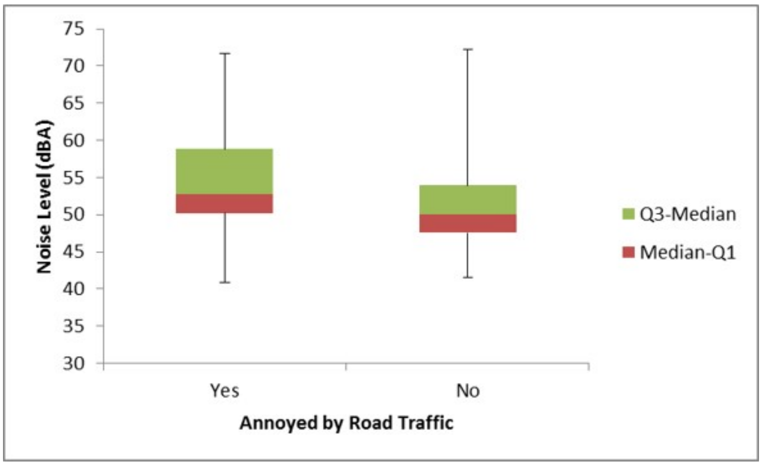
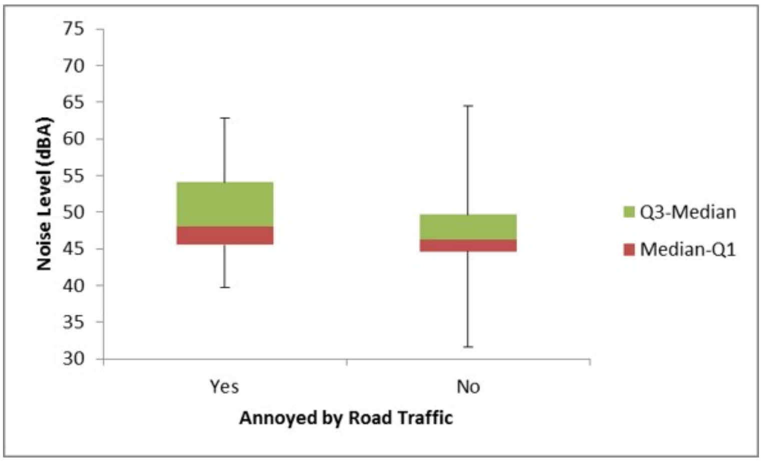


Figure 5.18 Waterview box plot



5.3.3 Time of day effects

Respondents were asked at what times of the day (both weekday and weekend) they were home based on six four-hour time periods starting at 7 am. The question 'when does noise annoy you?' was not asked because respondents are more likely to rate their annoyance based on an atypical event that recently occurred, such as being woken up by an emergency siren or being disturbed when watching television by a medical services helicopter overflight.

Noise in the evening and at night may have greater consequences compared with annoyance and disturbance in the daytime due to the activities and expectations respondents will have during these quieter periods. Within the European Union the L_{den} noise metric was adopted to compensate for increased annoyance and disturbance during the evening and at night by applying a weighted of 5 dB for the evening and 10 dB for the night. Similarly in New Zealand the L_{dn} is used for assessing and rating the noise from airports and ports by having a 10 dB weighting for the night-time period.

5.4 Survey comments

A number of questions sought comment on how the respondent was annoyed or bothered by road traffic noise or how rail noise affected them. In addition, a general narrative question was included to seek any feedback from the respondents and to establish whether there were any common themes. Table 5.11 provides a summary of the number of responses per topic for the two road traffic noise study areas.

Table 5.11 Summary of topics to the question 'In what way does noise from road traffic bother or annoy you?'

Category	Rail	SH1	Waterview
General traffic noise	3	28	5
Specific traffic noise	23	35	13
Driver behaviour	66	47	47
Heavy goods vehicles (HGVs)	16	15	13
Motorbikes	8	5	4
Police/ambulance sirens	6	6	3
Trains	3	1	0
Other noise sources	2	0	0

Category	Rail	SH1	Waterview
Non-noise issues	12	15	6
Lifestyle impact	19	66	32
Total responses to question	59 (24%)	92 (23%)	51 (32%)

The common themes noted by the respondent were:

- 'General traffic noise' includes comments on motorway noise, volume of traffic, congestion, local traffic diverted off the motorway, as well as general comments about levels of noise.
- 'Specific traffic noise' includes comments on the road surface, weather conditions (eg tyre noise on wet roads, or audibility with wind direction), noise from speed bumps, roadworks and issues with sound barriers (removal, reflections, or commenting that there are none).
- 'Driver behaviour' includes car stereos, speeding vehicles, excessive engine/exhaust noise, car horns, 'boy racer' behaviour, trucks braking and loads banging around.
- 'Non-noise issues' include concerns over parking (for example rail commuters or trucks parking in residential streets), safety concerns, vibration, pollution, visual effects and concerns over tree removal.
- 'Lifestyle impact' ranges from annoyance, through interference with normal daytime activities (including keeping windows shut or not wanting to sit outside) to sleep disturbance.

One comment can be included in several categories, for example if the respondent commented that they were annoyed by fast driving and car stereos, and this affected their sleep pattern, this would be included as two comments under 'driver behaviour' and two comments under 'lifestyle impact' (annoyance and sleep disturbance).

The number of comments about road traffic (the sum of general and specific traffic noise, driver behaviour, HGVs and motorbikes) were 116 for the rail study area, 130 for SH 1 and 82 for Waterview survey. The rail survey had the highest number of comments about driver behaviour (66).

There were typically a combination of concerns to do with driver behaviour, for example cars speeding, annoyance and safety concerns.

The lifestyle impact was highest for SH 1, with 66 comments about some sort of impact. Out of these comments, there were 16 comments about sleep disturbance.

Comments about night-time noise and sleep interference as a percentage of all lifestyle impact comments were 53% for the rail study area, 53% for SH 1 and 72% for Waterview.

Table 5.12 provides a summary for the rail traffic noise study area.

Table 5.12 Summary of topics to the question 'In what way does noise from trains bother or annoy you?'

Category	Rail
Lifestyle impact	27
Diesel trains noisy	8
Electric trains an improvement	5
Other noise	10
Vibration	6
Total responses to question	32 (13%)

The common themes noted by the respondent were:

- 'Lifestyle impact' includes any comment on annoyance or disturbance, including being frightened by the trains passing, as well as comments on night noise, interference with normal daytime activities and sleep disturbance.
- 'Other noise' includes track noise, level pedestrian crossings, train horns, brakes, hissing from doors opening/closing and station announcements.

Some respondents reported interference with activities such as not being able to continue a phone conversation while a train was passing, or always recording television programmes so they could be paused.

There were several comments that it was an improvement having electric trains as these were much quieter than the diesels. However, some respondents still reported being bothered by freight trains, particularly at night.

The highest number of comments (27) was about lifestyle impact.

Table 5.13 provides a summary of the comment topics provided by the respondents at the end of the questionnaire.

Table 5.13 Summary of other comments made at the end of the questionnaire

Category	Rail	SH1	Waterview
Aircraft noise	12	7	2
Industrial noise	3	2	3
Community noise	9	17	11
Traffic noise	0	11	1
Driver behaviour	6	10	4
Construction/roadworks	3	3	7
HGVs	5	5	2
Police helicopter/sirens	6	8	2
Other noise	2	1	0
Vibration	2	2	2
Lifestyle impact	6	7	3
Suggestions for improvements	7	16	1
Non-noise issues	4	4	4
Survey (positive/negative)	4/2	2/0	3/1
Total	71 (29%)	93 (23%)	35 (22%)

The common themes noted by the respondent were:

- 'Community noise' includes neighbours' parties, DIY and garden maintenance, dogs, fireworks, school noise, pool filtration units, house alarms, activities and equipment in parks.
- 'Driver behaviour' includes car stereos, speeding and 'boy racer' behaviour.
- 'Suggestions for improvements' includes installing speed bumps, noise barrier, better sound insulation for houses, reducing the speed limit, installing a pedestrian crossing and a smoother road surface.

- 'Non-noise issues' includes pollution, congestion, parking issues, safety concerns and problems with public transport.

Emergency vehicle sirens, particularly at night, bothered several respondents, mainly in the rail and SH 1study area. Police helicopters were also mentioned, hovering over a ground chase or waiting for clearance to fly over Auckland Airport.

Residents were also bothered by the number of heavy vehicles on residential streets, particularly when the motorway was diverted.

5.4.1 Summary

The commentary section of the questionnaire provided valuable supporting information on the annoyance results. For example, respondents may have been basing their annoyance score on individual noise events such as those originating from driver behaviour rather than the more constant noise from every day traffic conditions. Concentrating efforts to mitigate these events may have the benefit of reducing the perceived annoyance from land-based transport noise in general.

There were lots of suggestions for noise improvements in the SH 1 study area, with most concentrating on the use of noise barriers to reduce nearby noise levels. The introduction of noise barriers, where practicable, would have a consequential noise benefit but also a community perception of the relevant highway authority being a good neighbour and hence there could be a consequential reduction in the %HA following any improvement works. Additionally, noise improvements could be realised by introducing greater restrictions/policing of engine braking of large trucks and greater control of noisy cars and anti-social driver behaviour.

6 Conclusions and recommendations

6.1 Conclusions

The threshold at which an individual will be annoyed by road and rail noise will vary depending on their expectations and sensitivity to noise. Two influencing factors include where the individual lives and whether there has been a recent change in their noise environment following either a change in traffic conditions or the introduction of a new or altered road.

The research study sought to address both these factors by considering the use of study areas in rural zones as well as within urban areas and the inclusion of a recently opened new or altered road. Unfortunately, the need to survey at least 400 respondents within each study dictated that the main study areas had to be confined to the major urban areas where there was sufficient population density. Although there was the option of surveying multiple sites across the country and combining and aggregating the data, it was deemed appropriate to survey in three homogenous areas to ensure reliability of the outcomes, ie all individuals in each of the three study areas were exposed to the same conditions (diurnal pattern of traffic, classification of vehicle types and traffic flow numbers). Although the study concentrated on Auckland (to enable a relatively dense population to be surveyed), there were still limitations on the number of successful responses for both the rail noise element of the study and the new or altered road study area. Nevertheless the results from these two study areas were still considered statistically satisfactory to enable robust conclusions to be determined.

The questionnaire that was developed took on average 13 minutes to complete by telephone interview and included an option for each respondent to include additional commentary on noise. A number of respondents took the opportunity to provide feedback on a range of issues including driver behaviour, general lifestyle impacts and suggestions for improvement, which included the introduction of more noise barriers along SH 1 in Auckland.

The main findings from the research are:

- The data analysis shows that the sample for each study area has a greater proportion of older respondents compared with the general population as a whole and the sample has fewer respondents compared with the general population in the age range 18–24. Compared with the Auckland 2013 census data the sample across each study area has a greater proportion of retired individuals and a lower number of individuals in employment. This may have skewed some of the responses especially by those individuals who reside at home for a greater proportion of the time.
- The Waterview Connection study area has been subject to an extended period of construction works and the respondents rated ‘building and construction’ and ‘road works’ higher than the other two study areas. There is potential for the Waterview respondents to have been sensitised to noise in general having been subject to a major RoNS project, and also being aware the noise environment will change once the Waterview Connection has opened.
- Out of a list of 10 sources of environmental noise, road traffic was rated highest and for the rail study area, trains were rated the fifth most annoying noise source. The %HA analysis was found to compare well with other studies, although in each case the onset of annoyance occurred at a marginally lower sound level.
- Unsurprisingly, the rail study area reported a greater annoyance from rail traffic than both road study areas. Of the sample, 19% reported high annoyance from trains, whereas the other areas reported 1% and 5% respectively for SH 1 and Waterview (even though there are no rail lines within the study

areas). The most dominant source in terms of reported annoyance for each study area was road traffic noise, with Waterview achieving the highest score of 37%.

- In comparison with the other study areas, SH 1 on average has a lower occurrence of high annoyance. Excluding road traffic, the aggregate annoyance score for SH 1 was calculated to be 5%, whereas the other two study areas have an average high annoyance score of 15%.
- When comparing the onset of significant community response (scores of 20 %HA or more) for each study area and noise source, the rail study area has the highest onset at 62dB $L_{Aeq(24h)}$ compared with 59 and 58 dB $L_{Aeq(24h)}$ for SH 1 and Waterview respectively. These findings agree with those of Miedema and Vos (1998) who observed that rail noise was less annoying than road traffic noise for the same noise level. The analysis suggests that the New Zealand population is more sensitive to noise as the onset of significant community response occurs at lower sound levels, approximately 13 dB lower for rail and 6 dB lower for road, when compared with Miedema and Vos.
- Respondents were asked to provide general feedback on noise and other matters. It was noted that lifestyle impacts were a concern, which included general disturbance and interference with their quality of life. Interestingly driver behaviour accounted for the greatest number of comments with ‘boy racers’ and trucks being cited as the two most common sources of noisy events.

6.2 Recommendations

A number of observations were made which would assist with further studies:

- Difficulty was encountered when trying to achieve the target number of completed interviews with the relatively small population sizes within the Waterview Connection and rail study areas. A number of suggested improvements have been made for future studies. These include combining the results from multiple study areas, accepting a greater margin of error for the results and potentially altering the survey procedure to include face-to-face surveys.
- Although the questionnaire did not enquire as to how a respondent’s annoyance varied with time of day and day of the week, there is good evidence to show that respondents have greater annoyance at different times of the day and night. For future studies the inclusion of a ‘time of day’ annoyance question is recommended to determine whether there is a greater likelihood of more people being highly annoyed during the evening and night periods and therefore supporting the use of a noise metric weighting factor(s) for these time periods.
- Once there are steady-state traffic flows within the Waterview study area there will be an opportunity to re-survey from the middle of 2018, ie approximately one year after opening, to assess whether the annoyance curve has changed and respondents’ attitudes. Any future study should consider the statistical significance of the findings when compared with the overall sample of 157 respondents (37 telephone and 120 on-line questionnaires) in this study. It is hypothesised that the onset point is likely to increase accordingly and will follow a similar pattern to the existing situation for SH 1.

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Appendix A: Site selection

A1 Selected road sites – new roads

The following sections present a selection of five roads that have undergone recent modifications or upgrades. A description of the major works undertaken is provided along with traffic information and maps of each road.

A1.1 Neilson Street, Auckland

Neilson Street was upgraded between Church Street and Gloucester Park Road due to high usage. The works undertaken increased the capacity of Neilson Street by up to 25%. This involved major works that included:

- installation of two through-lanes in both directions
- an additional southbound transit lane.

The construction was completed in August 2013.

Table A.1 Traffic data for Neilson Street – as measured 26/3/2015 to 1/4/2015 by Auckland Transport

Average annual daily traffic	**28,000**
Percentage heavy vehicles	**13%**
Vehicle speed	**50 km/h (limit)**

Table A.2 Receiver details for Neilson Street survey site

Number of receivers within 500 m	**1,384**
Approximate percentage of residential receivers	**10–20%**

Figure A.1 Neilson Street survey site with receivers shown

A1.2 Glenfield Road, Auckland

Glenfield Road was upgraded between James Street South and the Sunset Road intersection. These upgrades add sufficient capacity for the predicted 3% per year increase in traffic volume. The major changes included in the upgrade were:

- installation of two lanes in each direction
- new raised and planted medians
- intersection upgrades
- upgraded cycle lanes, wider footpaths, street lights, and safety rails
- major road surface upgrade.

The construction was completed in June 2013.

Table A.3 Traffic data for Glenfield Road - as measured 11/6/2014 to 18/6/2014 by Auckland Transport

Average annual daily traffic	21,000
Percentage heavy vehicles	18.8%
Vehicle speed	50 km/h (limit)

Table A.4 Receiver details for Glenfield Road survey site

Number of receivers within 500 m	1,913
Approximate percentage of residential receivers	>95%

Figure A.2 Glenfield Road survey site with receivers shown

A1.3 Tiverton Road and Wolverton Street, Auckland

Tiverton Road and Wolverton Street were upgraded between New Windsor and New Lynn. This route is a major arterial and is responsible for significant traffic movements. The major works undertaken were:

- installation of two lanes in each direction between Clark St East and intersection of New Winsor Road and Maioro Street
- installation of traffic signals at five major intersections.

Construction was completed in March 2014.

Table A.5 Traffic data for Wolverton Street - as measured 13 May 2015 to 20 May 2014 by Auckland Transport

Average annual daily traffic	27,000
Percentage heavy vehicles	24.1%
Vehicle speed	50 km/h (limit)

Table A.6 Receiver details for Wolverton Street and Tiverton Road survey site

Number of receivers within 500 m	2,780
Approximate percentage of residential receivers	60–70%

Figure A.3 Wolverton Street and Tiverton Road survey site with receivers shown

A.1.4 SH 18, Auckland

Significant new roads were installed as part of the SH 18 Hobsonville deviation and SH 16 Brigham Creek extension. This work was part of the Upper Harbour Motorway and provides significant increases in capacity to and from northwest Auckland. The major works included:

- a total of 9 km of new four-lane motorway
- four new major interchanges
- one new flyover
- five new bridges
- four new roundabouts.

The construction was completed in 2011.

Table A.7 Traffic data for SH 18 as measured in 2014 by NZ Transport Agency

Average annual daily traffic	40,000
Percentage heavy vehicles	4%
Vehicle speed	100 km/h (limit)

Table A.8 Receiver details for SH 18 survey site

Number of receivers within 500 m	3,803
Approximate percentage of residential receivers	80–90%

Figure A.4 SH 18 survey site with receivers shown

A1.5 SH 20, Auckland

As part of the major upgrades being performed along the length of SH 20, major works were undertaken to extend SH 20 from Queenstown Road to Maioro Street. This work included:

- 4.5 km of new road
- two interchanges.

The work was completed in 2009. Further work was undertaken to increase the capacity of the Manukau Harbour Crossing, with this being completed in 2010.

Table A.9 Traffic data for SH 20 as measured in 2014 by the NZ Transport Agency

Average annual daily traffic	50,000
Percentage heavy vehicles	7%
Vehicle speed	100 km/h (limit)

Table A.10 Receiver details for SH 20 survey site

Number of receivers within 500 m	5,600
Approximate percentage of residential receivers	70–80%

Figure A.5 SH 20 survey site with receivers shown

A.2 Selected road sites – existing roads

A map of the survey location and a breakdown of the receivers are presented for each of the four proposed survey sites.

A.2.1 SH 1 – South Auckland

This state highway is the primary route that runs through the south of Auckland from Papakura to the Auckland CBD. It is subject to high traffic volumes and is a well-established route.

Table A.11 Traffic data for SH 1 – South Auckland – as measured in 2014 by the NZ Transport Agency

Average annual daily traffic	95,000
Percentage heavy vehicles	6%
Vehicle speed	100 km/h (limit)

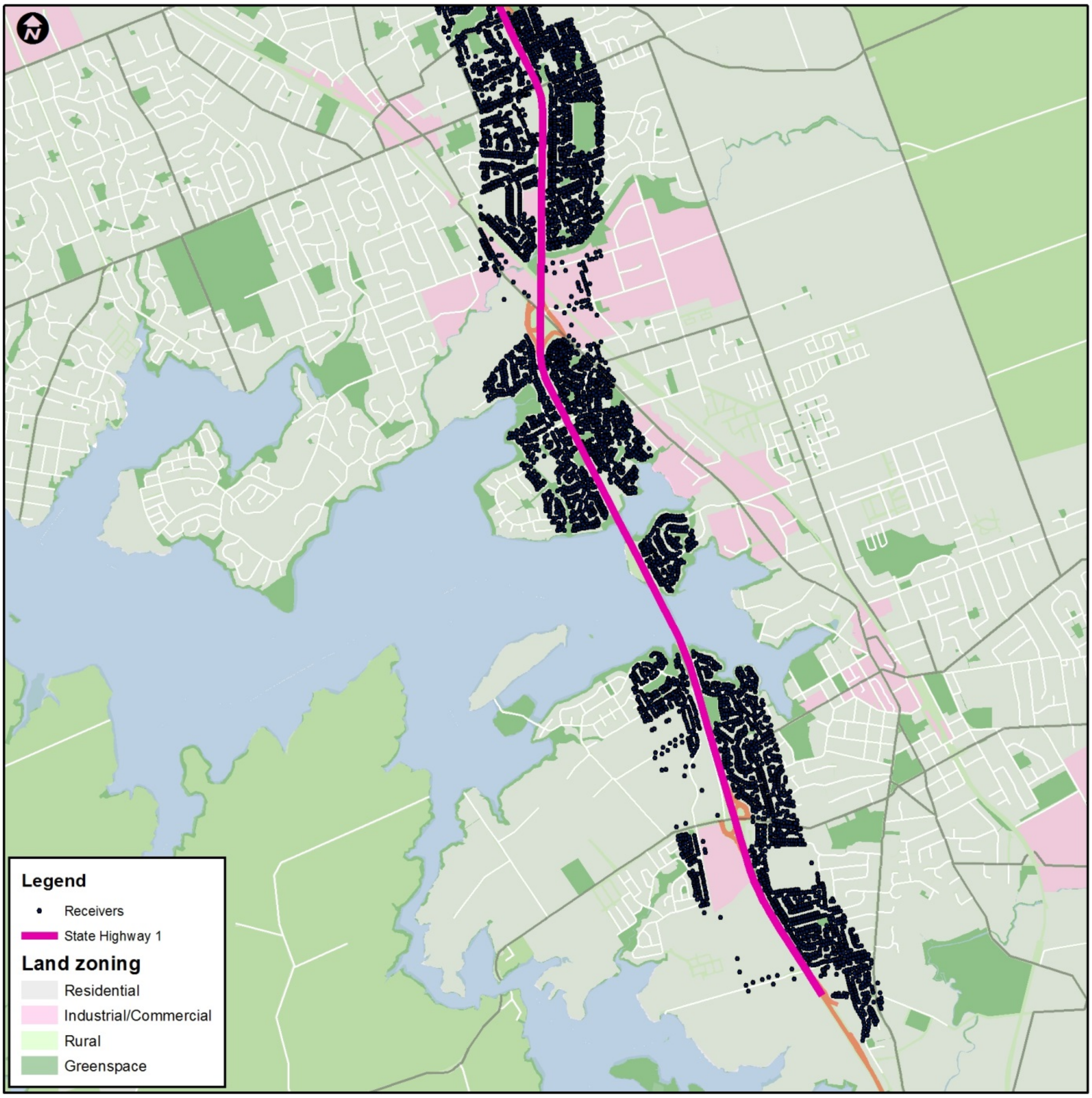
Table A.12 Receiver details for SH 1 – South Auckland survey site

Number of receivers within 500 m	25,681
Approximate percentage of residential receivers	70–90%

Figure A.6 SH 1 – South Auckland survey site with receivers shown (area 1 of 3)

Figure A.7 SH 1 – South Auckland survey site with receivers shown (area 2 of 3)

Figure A.8 SH 1 – South Auckland survey site with receivers shown (area 3 of 3)



A2.2 SH 1 – North Auckland

This state highway is the primary route that runs through the north of Auckland from the harbour bridge to the northern edge of Albany. It is subject to high traffic volumes and is a well-established route.

Table A.13 Traffic data for SH 1 – North Auckland as measured in 2014 by the NZ Transport Agency

Average annual daily traffic	164,000
Percentage heavy vehicles	5%
Vehicle speed	km/h (limit)

Table A.14 Receiver details for SH 1 – South Auckland survey site

Number of receivers within 500 m	6,599
Approximate percentage of residential receivers	70–90%

Figure A.9 SH 1 – North Auckland survey site with receivers shown (area 1 of 2)

Figure A.10 SH 1 – North Auckland survey site with receivers shown (area 2 of 2)

A2.3 SH 2 – Lower Hutt

SH 1 is a major route that runs from Wellington north through the Rimutakas. This survey site runs from the Hutt Road interchange to the Silverstream exit.

Table A.15 Traffic data for SH 2 – Lower Hutt - as measured in 2014 by NZ Transport Agency

Average annual daily traffic	40,000
Percentage heavy vehicles	4%
Vehicle speed	81 km/h (measured)

Table A.16 Receiver details for SH 2 – Lower Hutt survey site

Number of receivers within 500 m	4,539
Approximate percentage of residential receivers	70–80%

Figure A.11 SH 2 – Lower Hutt survey site with receivers shown (area 1 of 2)

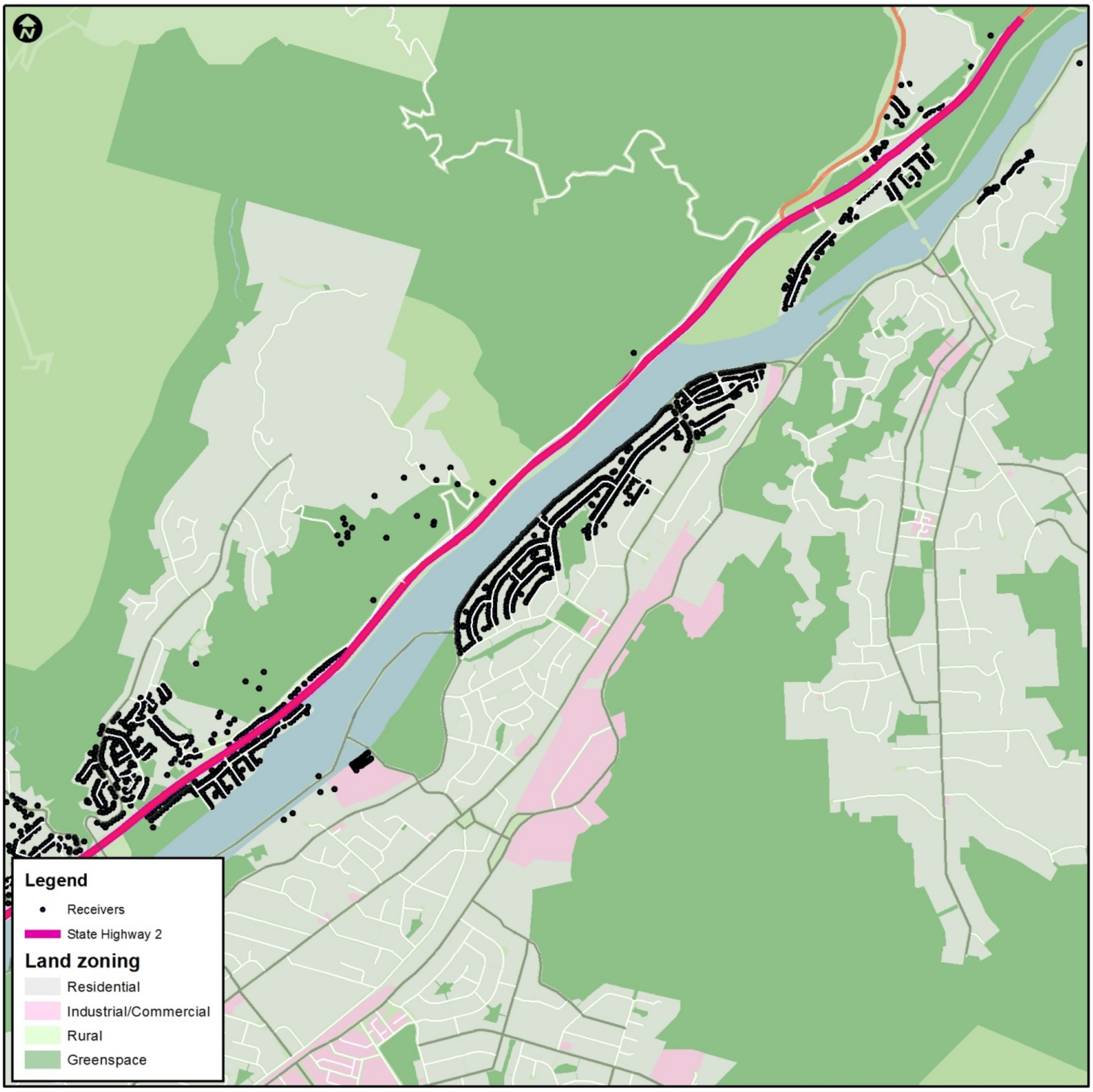
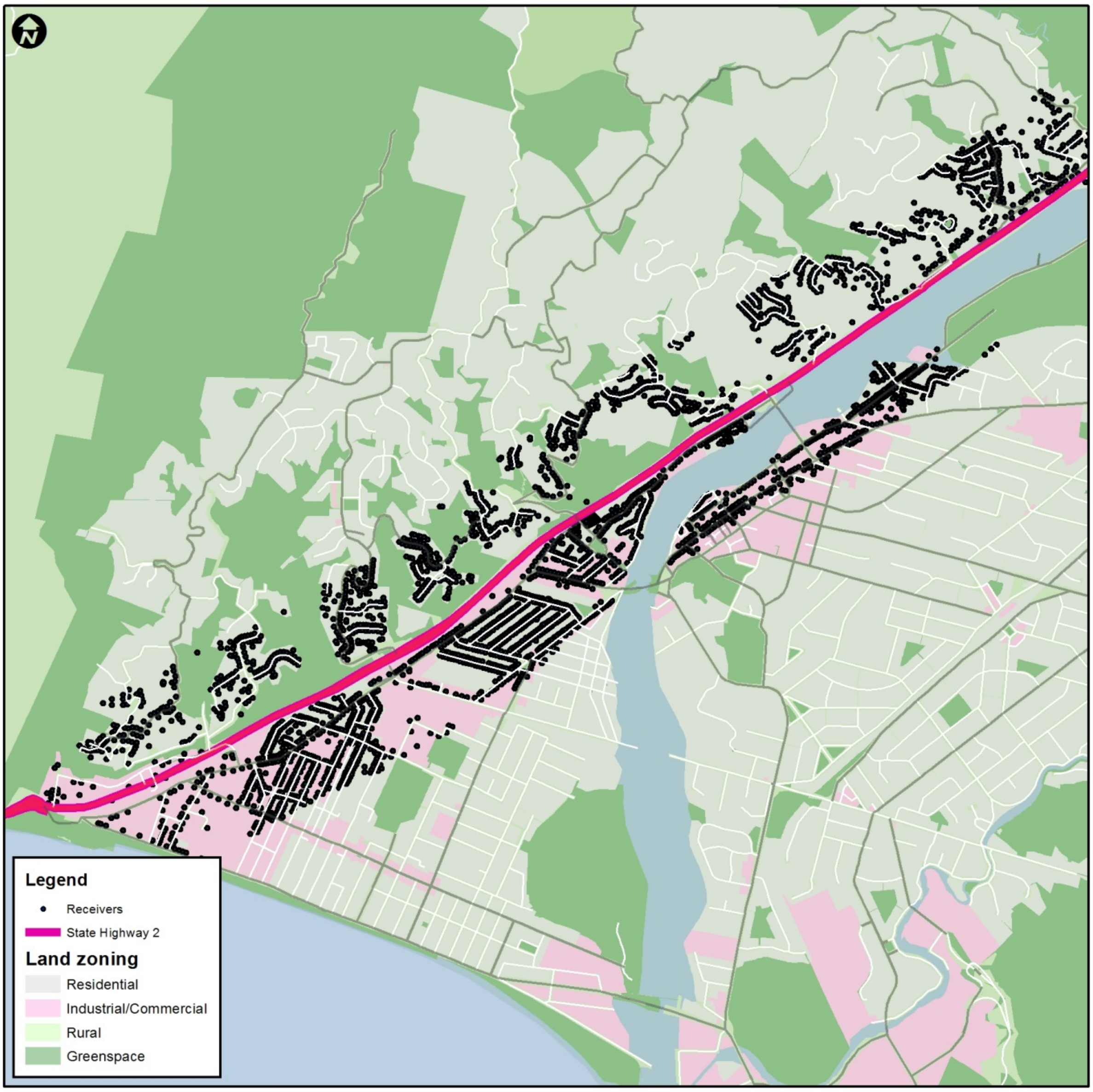


Figure A.12 SH 2 Lower Hutt survey site with receivers shown (area 2 of 2)



A2.4 SH 2 – Upper Hutt

SH 1 is a major route that runs from Wellington north through the Rimutakas. This survey site runs from 1 km south of the Moonshine Road exit to Te Marua.

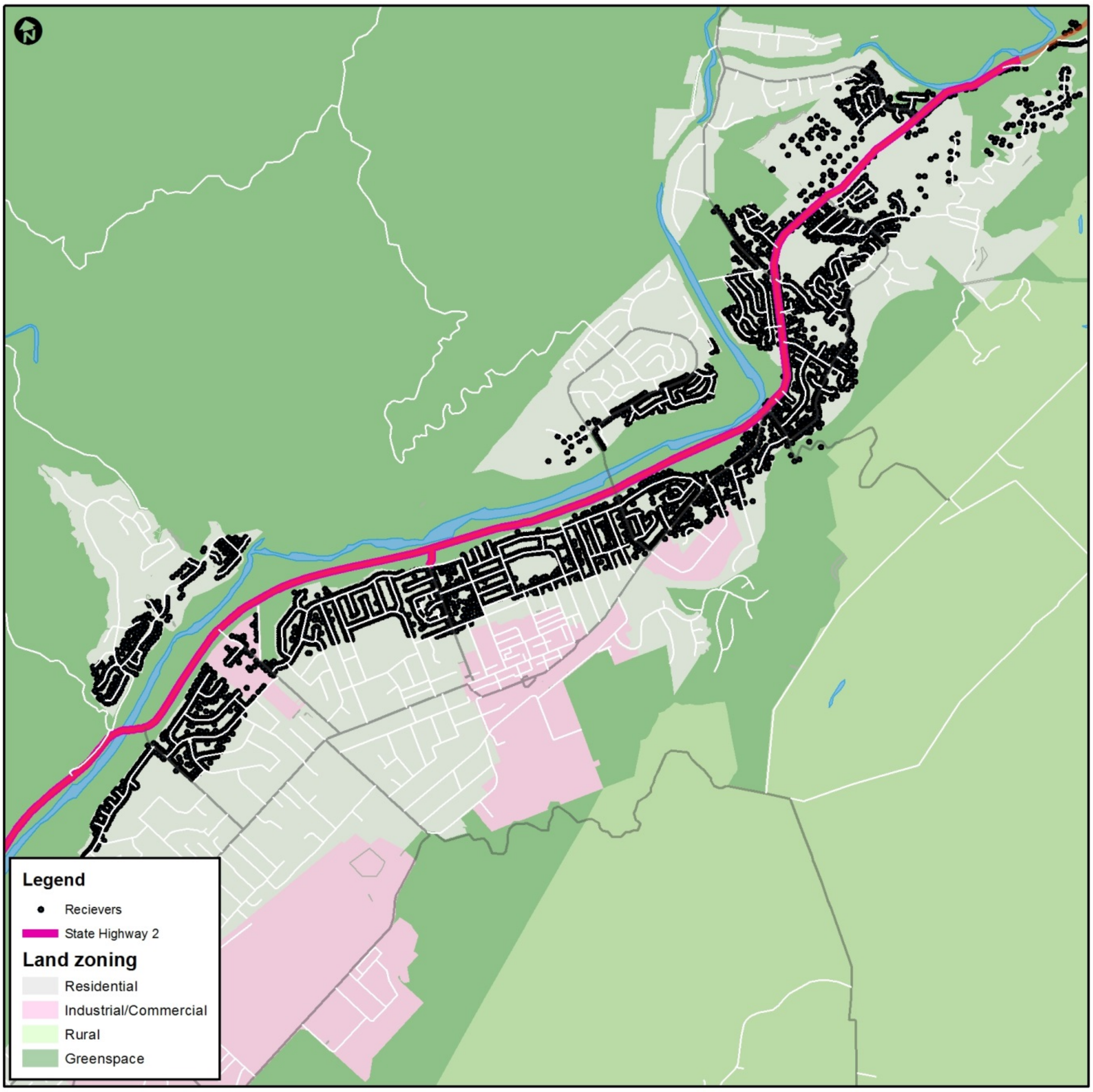
Table A.17 Traffic data for SH 2 – Upper Hutt, as measured in 2014 by the NZ Transport Agency

Average annual daily traffic	24,000
Percentage heavy vehicles	6%
Vehicle speed	80 km/h (limit)

Table A.18 Receiver details for SH 2 – Upper Hutt survey site

Number of receivers within 500 m	4,400
Approximate percentage of residential receivers	>95%

Figure A.13 SH 2 Upper Hutt survey site with receivers



A3 Selected rail sites

The rail sites presented are all located in Auckland. A number of alternative sites were considered but were ruled out due to insufficient rail movements or insufficient numbers of receivers. The rail sites are presented as either purely passenger rail or combined passenger and freight. These are broken into different sections.

A3.1 Passenger only lines

The passenger only lines on the southern and western lines are shown below with information about the traffic densities and the number of receivers.

Figure A.14 Passenger only sections of rail in Auckland.

Table A.19 Breakdown of rail traffic on passenger only lines

Line	Section of line	Total number of trains per day
Shared	Britomart - Newmarket	306
Southern	Newmarket - Penrose	185
Southern	Penrose - Westfield	135
Southern	Puhinui - Manukau	128
Western	Newmarket - Swanson	104

Table A.20 Number of receivers for each section of line, for passenger only lines

Section of line	Number of receivers within 150 m	Approximate percentage of residential receivers
Britomart – Newmarket	1,735	10–20%
Newmarket – Penrose	1,708	20–30%
Penrose – Westfield	65	0%
Puhinui – Manukau	24	0%
Newmarket – Swanson	6,307	70–80%

Figure A.15 Receivers and zoning along passenger only lines (area 1 of 3)

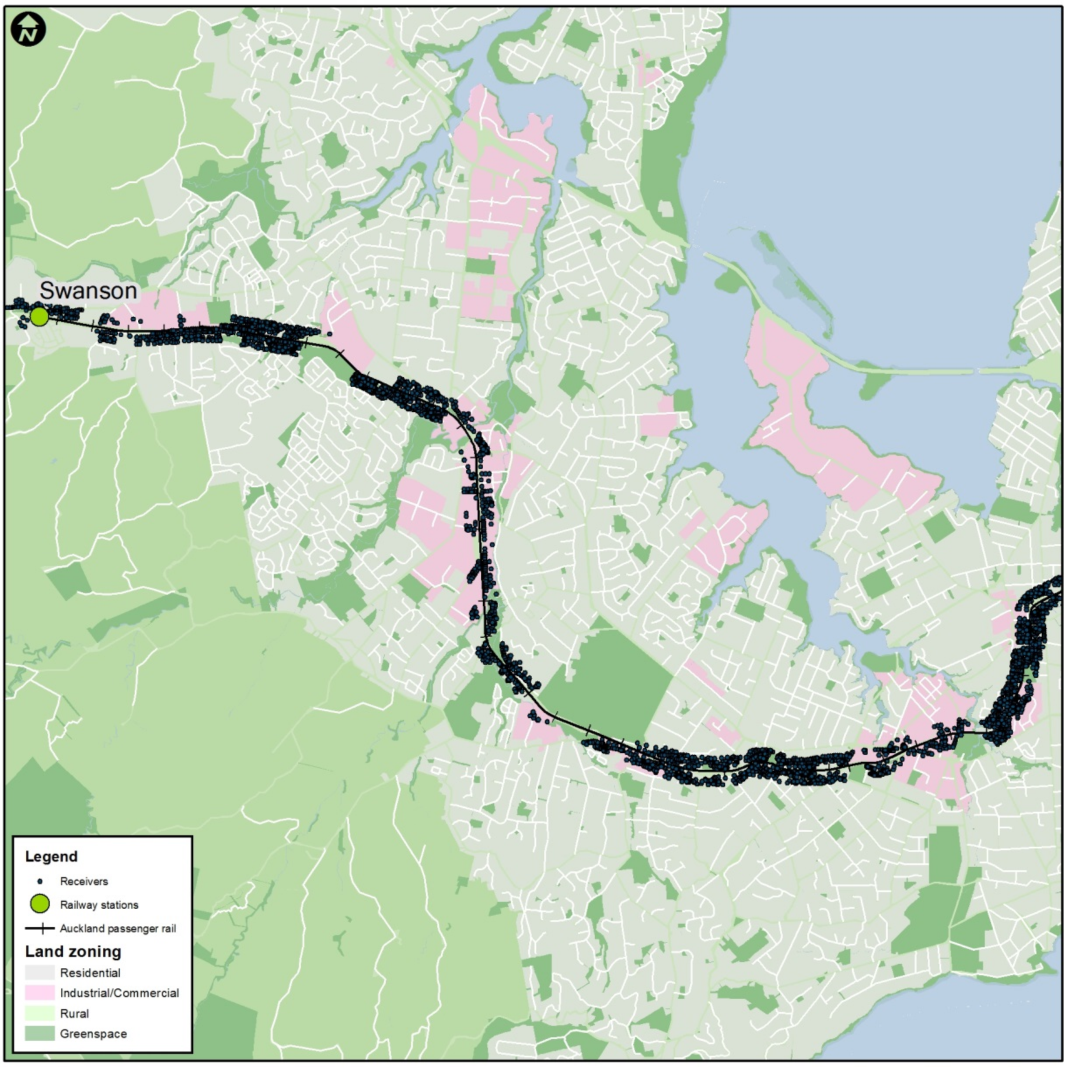


Figure A.16 Receivers and zoning along passenger only lines (area 2 of 3)

Figure A.17 Receivers and zoning along passenger only lines (area 3 of 3)

A3.2 Passenger and freight lines

The combined passenger and freight lines in Auckland on the southern and eastern lines are shown below with information about the traffic densities and the number of receivers.

Figure A.18 Combined passenger and freight lines in Auckland

Table A.21 Breakdown of rail traffic on combined passenger and freight lines

Line	Section of line	Total number of trains per day	Freight percentage of rail traffic
Shared	Westfield – Puhinui	263	16%
Southern	Puhinui – Papakura	149	9%
Eastern	Britomart – Westfield	128	14%
Southern	Papakura – Pukekohe	64	28%

Table A.22 Number of receivers for each section of line, for combined passenger and freight lines

Section of line	Number of receivers within 150m	Approximate percentage of residential receivers
Westfield – Puhinui	1,174	60–70%
Puhinui – Papakura	2,160	40–50%
Britomart – Westfield	2,262	30–40%
Papakura – Pukekohe	861	90–100%

Figure A.19 Receivers and zoning along combined passenger and freight lines (area 1 of 5)

Figure A.20 Receivers and zoning along combined passenger and freight lines (area 2 of 5)

Figure A.21 Receivers and zoning along combined passenger and freight lines (area 3 of 5)

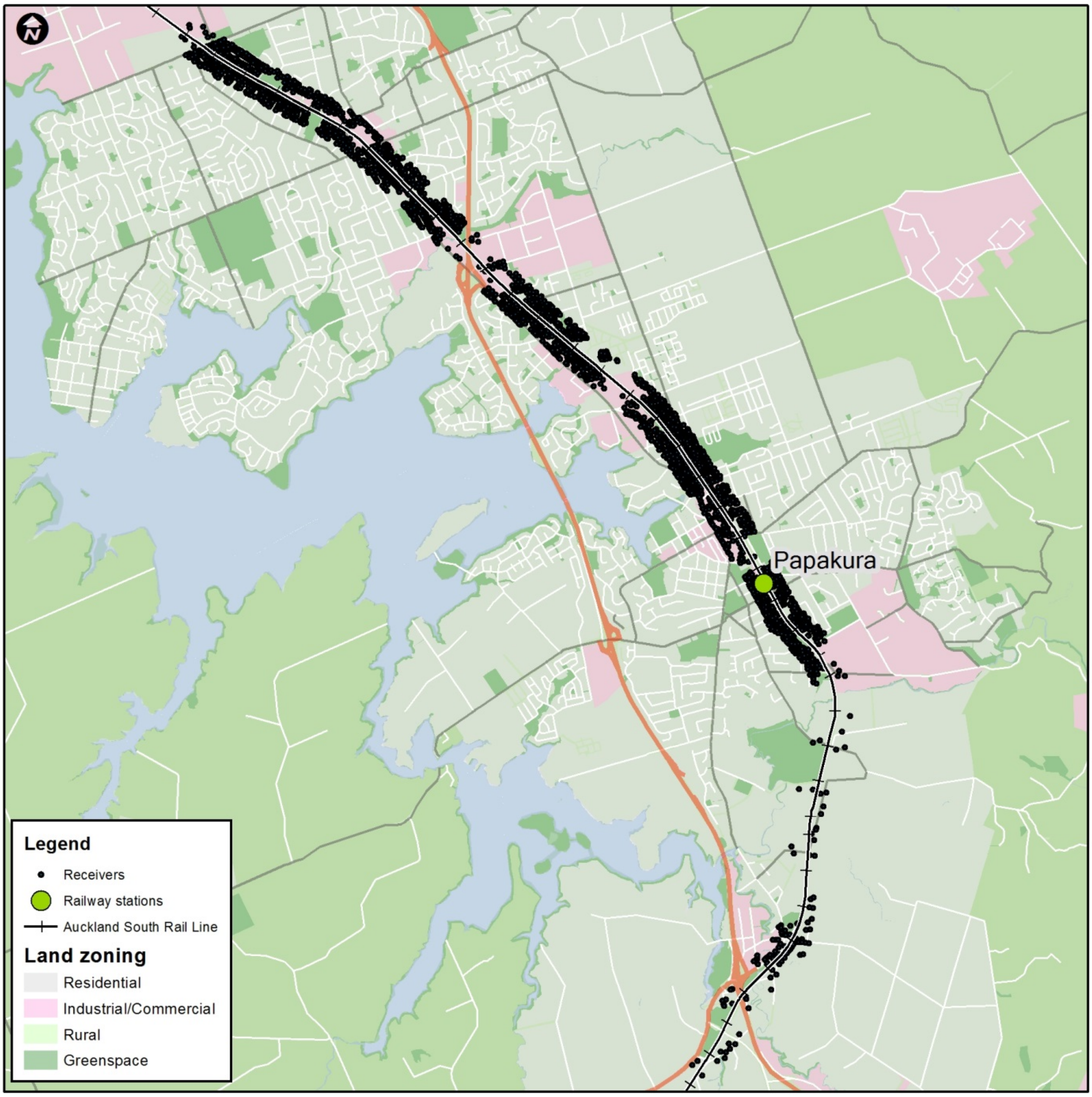


Figure A.22 Receivers and zoning along combined passenger and freight lines (area 4 of 5)

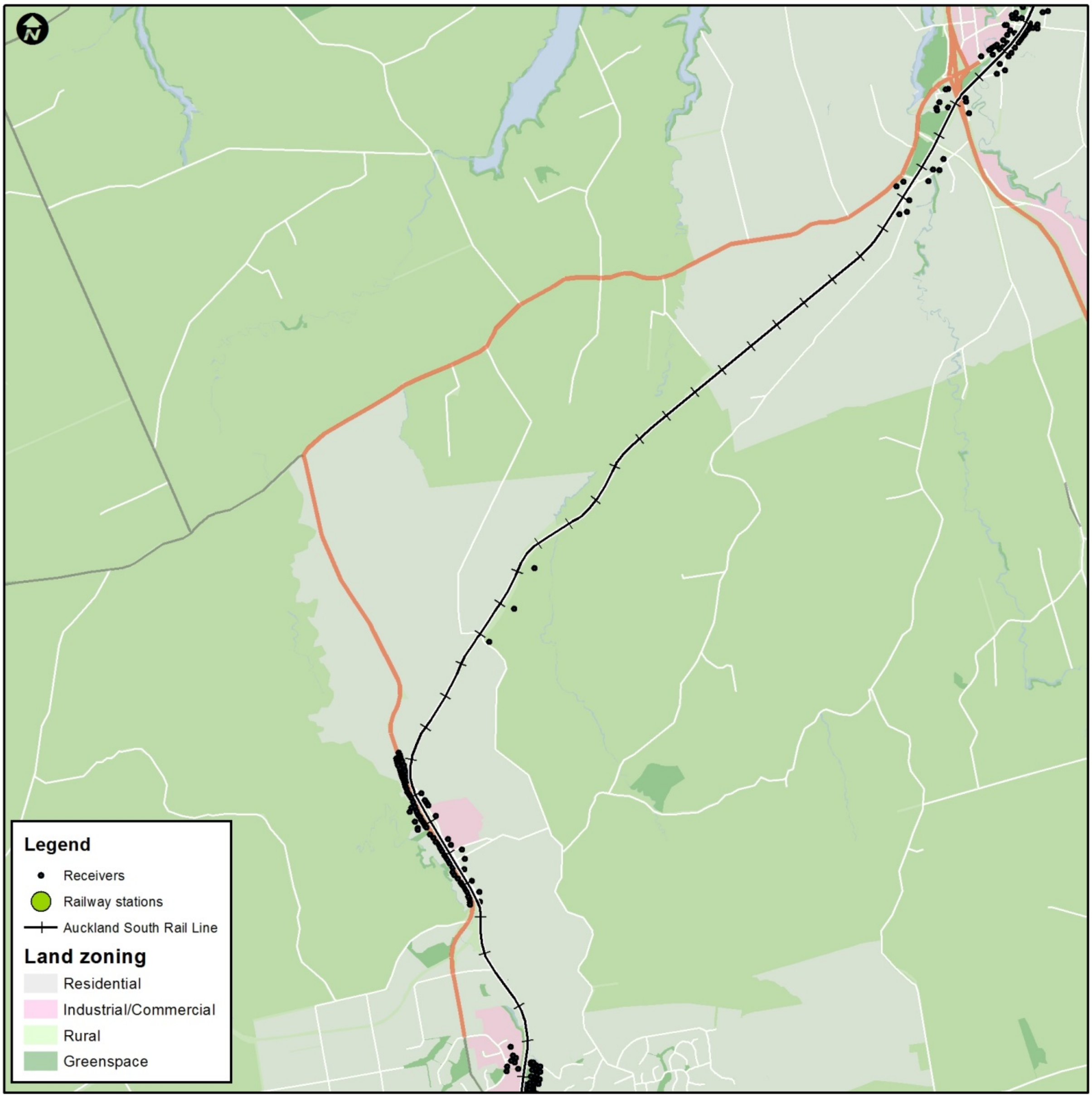
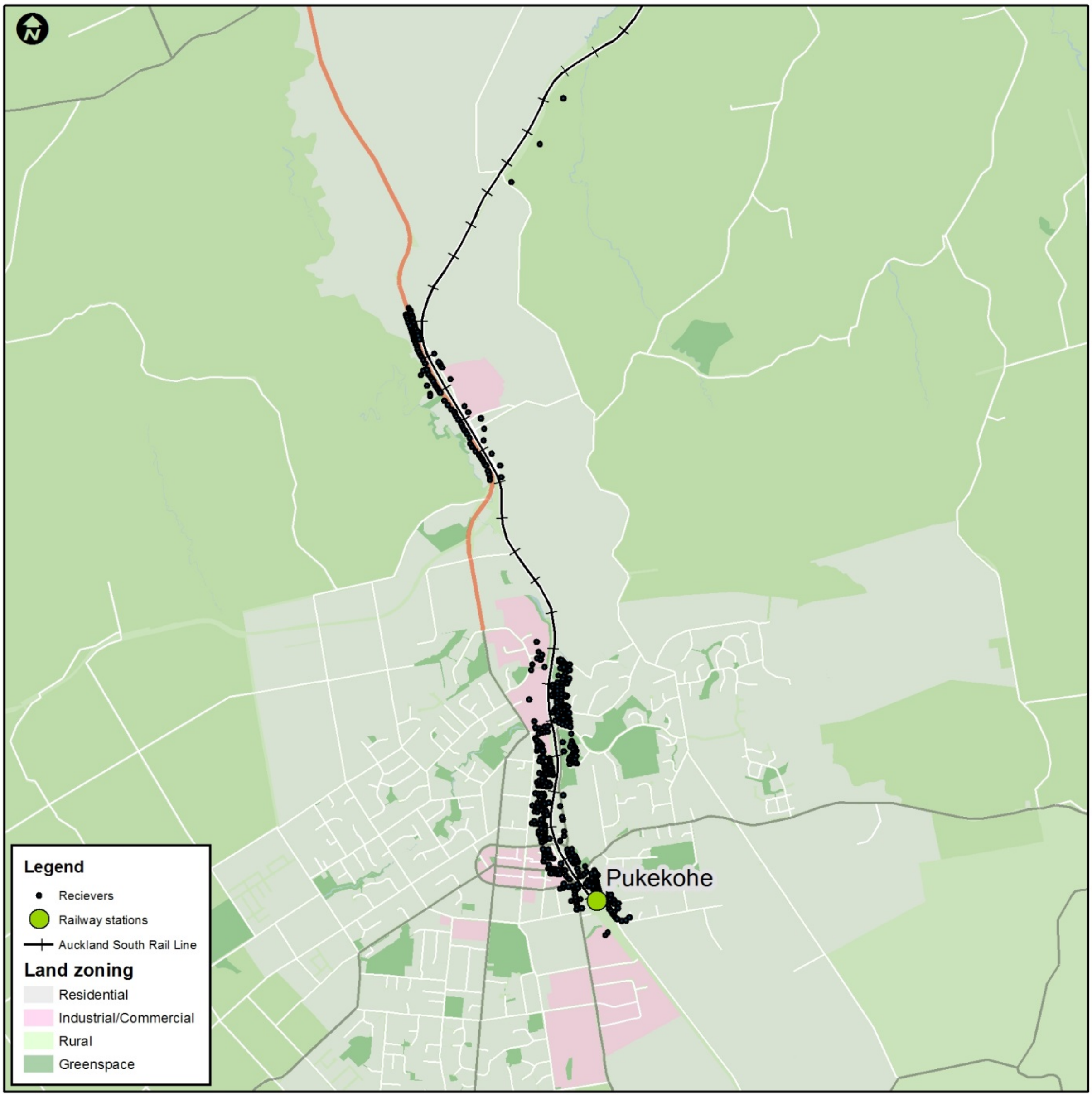


Figure A.23 Receivers and zoning along combined passenger and freight lines (area 5 of 5)



Appendix B: Study questionnaire

SURVEY ON THE IMPACT OF ENVIRONMENTAL NOISE

Research New Zealand #4792

DATE 2016

Good morning/afternoon/evening, is ^I home?

My name is ^I from Research New Zealand. We are conducting a survey with people in your neighbourhood about the effects of noise. We recently sent your household a letter about this.

The survey takes about 10-15 minutes depending on your answers.

Reintroduce if necessary:
We are conducting a survey with people in your neighbourhood about the effects of noise.

Confirm participation:
Would you be interested in taking part? It takes about 10-15 minutes depending on your answers.

Thank you. Can I just confirm that you are 18 years or over?

Is now a good time?

If no: When would be a more convenient time? **Make appointment.**

Background information only if needed:
This is genuine research. I'm not selling anything.

The survey is being sponsored by the New Zealand government and particularly, the New Zealand Transport Agency.

AECOM New Zealand is a large engineering design consultancy and technical service provider. You can find out more by going to www.aecom.com

Information provided is confidential. We report summary results about groups; we do not identify which individuals have said what.

Read This interview will be recorded for quality control and training purposes.

1. **CODE RESPONDENT'S SEX – DO NOT READ THIS QUESTION**

   1 .....Male
   2 .....Female

1a **DERIVED VARIABLE BASED ON NOISE LEVEL GROUPING**

   1 .....Low
   2 .....Medium
   3 .....High

2. First of all, I'd like to ask you some questions about yourself. Could you please tell me which of the following age groups you come into? **READ**

   1 18-24
   2 25-34
   3 35-44
   4 45-54
   5 55-64
   6 65-74
   7 .....75 years and over
   8 .....Under 18 years of age ****Do not read**] terminate**
   99 ...Refused ****Do not read**] terminate**

AGE TERMINATION IF 8: THANK YOU FOR YOUR TIME BUT FOR THIS SURVEY WE NEED TO SPEAK TO PEOPLE 18 YEARS OF AGE OR OLDER.

AGE TERMINATION IF 99: THANK YOU FOR YOUR TIME BUT FOR THIS SURVEY WE NEED TO KNOW THE AGE OF RESPONDENTS.

3. And which of the following ethnic group or groups do you belong to? **READ, CODE MANY**

   1 .....New Zealand European (or Pakeha)
   2 .....Maori
   3 .....Samoan
   4 .....Cook Island Maori
   5 .....Another Pacific nation (Tongan, Niuean, Tokelauan, Fijian)
   6 .....Chinese
   7 .....Indian
   96 ...Another ethnic group such as Dutch, Japanese or South African? Please say what it is **Specify**
   98 ...Don't know
   99 ...Refused

4. And are you ...? **Read Code many**

   1 .....An employer
   2 .....Self employed
   3 .....A salary or wage earner
   4 .....Retired
   5 .....A full time home-maker
   6 .....A student
   7 .....Unemployed
   8 .....Other beneficiary
   99 ...Refused **Do not read**

5. [moved]

6. [moved]

7. [moved]

8. Including yourself, how many people normally live in your household?

   1 .....One
   2 .....Two
   3 .....Three or more
   98 ...Don't know
   99 ...Refused

9. Do you own or rent this house?

   1 .....Own (with/without mortgage)
   2 .....Rent
   3 .....Board
   4 .....Other (e.g. live with parents)
   98 ...Don't know
   99 ...Refused

Sources of annoying noise

10. I'm now going to ask you some questions about different sources of noise, which might or might not annoy you **when you are at home**.

Thinking about the last 12 months or so, when you are at home, about how much does noise from … [**RD. insert first option**] bother, disturb or annoy you? Please answer using a scale from not at all, slightly, moderately, very, or extremely?

And what about…..? **Note to interviewer Read each noise source**

	Slightly			Extremely	DK	Not at all
a. Aircraft	1	2	3	4	98	99
b. Alarms or sirens						
c. Animals	1	2	3	4	98	99
d. Building and construction	1	2	3	4	98	99
e. Local businesses, factories or industry	1	2	3	4	98	99
f. Pubs and nightclubs	1	2	3	4	98	99
g. Neighbours, including their children	1	2	3	4	98	99
h. Road traffic	1	2	3	4	98	99
i. Road works	1	2	3	4	98	99
j. Trains	1	2	3	4	98	99

11. [Derived variable] If 10h (road traffic) AND 10j (trains)=3/4, select one at random:

1 Road traffic -→ **Go to 12**

2 Train → **Go to 19**

If 10h (road traffic) =3/4 AND 10j (trains) DOES NOT=3/4 →Go to 12:

If 10j (trains) =3/4 AND 10h (road traffic) DOES NOT=3/4 →Go to 19:

If 10h (road traffic) AND 10j (trains) DO NOT=3/4 →Go to 26:

Impact of noise from road traffic

12. Thinking in particular about noise from **road traffic**.

On a scale from 0-10, where 0='not at all annoyed' and 10='extremely annoyed', what number from zero to 10 best shows how much you are bothered, disturbed or annoyed by noise from **road traffic**?

0 .....0 – Not at all annoyed
1 1
2 2
3 3
4 4
5 .....5 – Midpoint
6 6
7 7
8 8
9 9
10 ...10 – Extremely annoyed
98 ...Don't know

13. In what ways does noise from **road traffic** bother or annoy you? **PROBE FOR CLEAR ANSWER**

96 ...Answer **Specify**
98 ...Don't know

14. So we can understand when you might be affected by noise from **road traffic** while you are at home, thinking about the **days of a typical week**, can you tell me whether you are likely to be home or in the immediate neighbourhood close to your home for each of the following times? **Read CODE MANY**

1 .....Between 7am and 11am in the morning
2 .....Between 11am and 3pm
3 .....Between 3pm and 7pm in the afternoon and the early part of the evening
4 .....Between 7pm and 11pm
5 .....Between 11pm and 3am late at night and early in the morning
6 .....Between 3am and 7am
98 ...Don't know ****Do not read****
99 ...Refused ****Do not read****

15. And what about the **days of a typical weekend**? Can you tell me whether you are likely to be home or close to your home for each of the following times? **Read CODE MANY**

1 .....Between 7am and 11am in the morning
2 .....Between 11am and 3pm
3 .....Between 3pm and 7pm in the afternoon and the early part of the evening
4 .....Between 7pm and 11pm
5 .....Between 11pm and 3am late at night and early in the morning
6 .....Between 3am and 7am
98 ...Don't know ****Do not read****
99 ...Refused ****Do not read****

16. **If Q8 = 1 skip to Q26 else ask** In general, would you say the other people who live in your home find noise from **road traffic** they hear while they are at home more or less annoying than you do, or about the same?

1 More annoying
2 Less annoying
3 .....About the same
98 ...Don't know

17. And during the **days of a typical week**, are the other people who normally live in your household usually at home or close to your home …? **Read Code Many**

1 .....Between 7am and 11am in the morning
2 .....Between 11am and 3pm
3 .....Between 3pm and 7pm in the afternoon and the early part of the evening
4 .....Between 7pm and 11pm
5 .....Between 11pm and 3am late at night and early in the morning
6 .....Between 3am and 7am
98 ...Don't know ****Do not read****
99 ...Refused ****Do not read****

18. And during the **days of a typical weekend**, are they usually at home or close to home … **Read Code Many**

1 .....Between 7am and 11am in the morning
2 .....Between 11am and 3pm
3 .....Between 3pm and 7pm in the afternoon and the early part of the evening
4 .....Between 7pm and 11pm
5 .....Between 11pm and 3am late at night and early in the morning
6 .....Between 3am and 7am
98 ...Don't know ****Do not read****
99 ...Refused ****Do not read****

Impact of noise from trains

19. Thinking in particular about noise from **trains**.

On a scale from 0-10, where 0='not at all annoyed' and 10='extremely annoyed', what number from zero to 10 best shows how much you are bothered, disturbed or annoyed by noise from **trains**?

0 .....0 – Not at all annoyed
1 1
2 2
3 3
4 4
5 .....5 – Midpoint
6 6
7 7
8 8
9 9
10 ...10 – Extremely annoyed
98 ...Don't know

20. In what ways does noise from **trains** bother or annoy you?

96 ...Answer **Specify**
98 ...Don't know

21. So we can understand when you might be affected by noise from **trains** while you are at home, thinking about the **days of a typical week**, can you tell me whether you are likely to be home or in the immediate neighbourhood close to your home for each of the following times? **Read Code Many**

1 .....Between 7am and 11am in the morning
2 .....Between 11am and 3pm
3 .....Between 3pm and 7pm in the afternoon and the early part of the evening
4 .....Between 7pm and 11pm
5 .....Between 11pm and 3am late at night and early in the morning
6 .....Between 3am and 7am
98 ...Don't know ****Do not read****
99 ...Refused ****Do not read****

22. And what about the **days of a typical weekend**? Can you tell me whether you are likely to be home or close to your home for each of the following times? **Read Code Many**

1 .....Between 7am and 11am in the morning
2 .....Between 11am and 3pm
3 .....Between 3pm and 7pm in the afternoon and the early part of the evening
4 .....Between 7pm and 11pm
5 .....Between 11pm and 3am late at night and early in the morning
6 .....Between 3am and 7am
98 ...Don't know ****Do not read****
99 ...Refused ****Do not read****

23. **If Q8 = 1 skip to Q26 else ask** In general, would you say the other people who live in your home find noise from **trains** they hear while they are at home more or less annoying than you do, or about the same?

1 More annoying
2 Less annoying
3 .....About the same
98 ...Don't know

24. And during the **days of a typical week**, are the other people who normally live in your household usually at home or close to your home …? **Read Code Many**

1 .....Between 7am and 11am in the morning
2 .....Between 11am and 3pm
3 .....Between 3pm and 7pm in the afternoon and the early part of the evening
4 .....Between 7pm and 11pm
5 .....Between 11pm and 3am late at night and early in the morning
6 .....Between 3am and 7am
98 ...Don't know ****Do not read****
99 ...Refused ****Do not read****

25. And during the **days of a typical weekend**, are they usually at home or close to home … **Read Code Many**

1 .....Between 7am and 11am in the morning
2 .....Between 11am and 3pm
3 .....Between 3pm and 7pm in the afternoon and the early part of the evening
4 .....Between 7pm and 11pm
5 .....Between 11pm and 3am late at night and early in the morning
6 .....Between 3am and 7am
98 ...Don't know ****Do not read****
99 ...Refused ****Do not read****

Transport Use

26. Which of the following forms of transport have you used in the last 3 months to get around the area in which you live (**If 1/3 or 6 coded in 4 ask:** and work/study in?) **Read. Code many**

1 .....Bus
2 .....Train
3 .....Taxi
4 .....Van
5 .....Truck
6 .....Private car, as a driver
7 .....Private car, as a passenger
8 .....Motorcycle or scooter
9 .....Bicycle
10 ...Walking
96 ...Other **Specify** ****Do not read****
98 ...Don't know **;E** ****Do not read****

27. **If 1/3 or 6 coded in 4:** And what is the **main** form of transport you use to travel to work/study. That is, the one you use to go the **greatest** distance.

1 .....Bus
2 .....Train
3 .....Taxi
4 .....Van
5 .....Truck
6 .....Private car, as a driver
7 .....Private car, as a passenger
8 .....Motorcycle or scooter
9 .....Bicycle
10 ...Walking
96 ...Other **Specify**
97 ...Don't/Work from home
98 ...Don't know

28. Do you personally own a… **Read. Code many**

1 .....Car
2 .....Motorcycle
3 .....Scooter
4 .....Van, 4WD
5 .....Or other motor vehicle?
97 ...No, do not own a motor vehicle **;E** ****Do not read****
99 ...Refused **;E** ****Do not read****
98 ...Don't know

RECRUITING FOR SECOND HOUSEHOLD INTERVIEW

29. **If location=SH1 skip to Q33, else ask** Thanks for that. We would also like to talk to other people aged 18 and over in your household about this survey. Are there any people of this age in your household who might be interested in taking part sometime during the next couple of weeks?

1 .....Yes
2 .....No

30. **if 29=2 go to 33** Thanks for that. Could you give me their name please?

1 .....**Specify name**
98 ...Don't know
99 ...Refused

31. You can tell him/her that the survey is about noise but please don't tell them specific questions you have answered, as it might influence the way they answer some questions. If we did call them about this survey, when would be the best time? **Interviewers: please make appointments for next day or later.**

1 .....**Specify appointment**
2 .....Doesn't matter / potluck

32. And what is the best phone number or email address to contact them on?

1 .....**Specify phone number or email address**
2 .....No change.

Closing questions

33. Those are all the questions I have. Do you have any other comments you'd like to make about the subject of this interview?

1 .....Comments **Specify**
2 .....No

May I please confirm your name in case my supervisor needs to check on the quality of this interview? **Record first and last name**

Thank you very much for your help. My name is **Q0IV** from Research New Zealand. If you have enquiries about this survey, please ring the Project Manager, Aaron McKay-Valentine, on our toll-free number: 0800 500 168. (Wellington respondents 499-3088).

Appendix C: Pre-notification letters

[Pre-notification letter for those with phone numbers]

29 September 2016

Dear xxx

A survey about the effects of noise in your neighbourhood

We are conducting a survey with the people who live in your neighbourhood about **the effects of noise**. This could be the noise from a range of different sources, including nearby roads, businesses or factories, parks and recreational grounds, or railroads and airports.

The survey is being completed for AECOM and the New Zealand Government. The purpose of the survey is to measure the impact of noise on people's wellbeing so they can be taken into account in future planning.

Your household has been randomly selected to take part in the survey and one of our interviewers may ring in the next few weeks to invite someone to answer the survey questions. No preparation is required and the survey will take no more than about 10-15 minutes to complete over the telephone.

It's your choice whether you take part in the survey, but as it is important that we interview a cross-section of people in your neighbourhood, we would appreciate someone in your household taking part. If you have any questions or you would like additional information about the survey, you can call me on our Freephone 0800 500 168, email us at noise@researchnz.com or visit our website (www.researchnz.com) and go to the 'Current surveys' page.

Your answers to the survey questions will analysed together with information about the noise levels in your neighbourhood. Your household will not be identifiable in any report that is prepared based on the survey results; that is all the information you provide will be anonymised as soon the survey has been completed.

Thank you for your help.

Yours sincerely

RNZ REF:

FREQUENTLY ASKED QUESTIONS

What's the purpose of the survey?	To gather information from people in your neighbourhood about the effects of noise. This information will be used in future planning.
Who will be conducting this research?	Research New Zealand is conducting the survey on behalf of AECOM and the New Zealand Government.
Who is AECOM?	AECOM New Zealand is a large engineering design consultancy and technical service provider. You can find out more about AECOM by visiting their website www.aecom.com
How did they get my name and address?	Your name and address were randomly selected along with many others from your neighbourhood through the Electoral Rolls and your household telephone number from the White Pages.
When does the survey have to be completed by?	We are aiming to complete the survey by the end of October 2016 and, therefore, your household may get a call from one of our interviewers during this time. The survey will take between 10-15 minutes to complete.
Is the survey confidential?	Yes, it is completely confidential. Your household's answers to the survey will be depersonalised as soon as the survey is completed, which means that the person in your household who is interviewed, as well as your household, will not be identifiable in any report that is prepared. Research New Zealand is bound by the Professional Code of Practice of the European Society for Marketing and Opinion Research Inc. (the largest professional organisation of its type in the world), which prohibits us from identifying any person who takes part in a survey unless we have explicit consent from them to do so.
Do I have to take part in the survey?	No, your household doesn't have to do the survey. Participation in this survey is completely voluntary, but it is important that as many people as possible do so we can have a representative picture of the effects of noise in your neighbourhood.
What if I want to find out more about it?	If you have any queries about the survey, please call Aaron McKay-Valentine (Project Manager, Research NZ) on Freephone: 0800 500 168 or email noise@researchnz.com

[Pre-notification letter for those without phone numbers]

5 April 2017

Dear

A survey about the effects of noise in your neighbourhood

We are conducting an online survey with the people who live in your neighbourhood about **the effects of noise**. This could be the noise from a range of different sources, including nearby roads, businesses or factories, parks and recreational grounds, or railroads and airports.

The survey is being completed for AECOM and the New Zealand Government. The purpose of the survey is to measure the impact of noise on people's wellbeing so they can be taken into account in future planning.

Your household has been randomly selected to take part in the survey. No preparation is required and the survey will take no more than about 10 minutes to complete by going to www.researchnz.com, selecting 'Current online surveys' and then selecting 'Environmental Noise Survey' under 'AECOM', and using your unique login ID and password.

IDNO: <<insert>> **Password: <<insert>>**

Every household who completes the survey will go into a draw to win one of three $150 grocery vouchers.

It's your choice whether you take part in the survey, but as it is important that we survey a cross-section of people in your neighbourhood, we would appreciate someone in your household taking part. If you have any questions or you would like additional information about the survey, you can call Aaron McKay-Valentine on our Freephone 0800 500 168 or email us at noise@researchnz.com

Your answers to the survey questions will analysed together with information about the noise levels in your neighbourhood. Your household will not be identifiable in any report that is prepared based on the survey results; that is all the information you provide will be anonymised as soon the survey has been completed.

Thank you for your help.

Yours sincerely

FREQUENTLY ASKED QUESTIONS

What's the purpose of the survey?	To gather information from people in your neighbourhood about the effects of noise. This information will be used in future planning.
Who will be conducting this research?	Research New Zealand is conducting the survey on behalf of AECOM and the New Zealand Government.
Who is AECOM?	AECOM New Zealand is a large engineering design consultancy and technical service provider. You can find out more about AECOM by visiting their website www.aecom.com
How did they get my contact details?	Your contact details were randomly selected along with many others from your neighbourhood through the Electoral Rolls and/or the White Pages.
Can I do the survey by telephone?	Yes, just call Research NZ on 0800 500 168 with your login ID ready (<insert>), and they will arrange a time for one of their interviewers to take you through the survey over the telephone.
When does the survey have to be completed by?	We are aiming to complete the survey by the end of April 2017. The survey will take about 10 minutes to complete.
Is the survey confidential?	Yes, it is completely confidential. Your household's answers to the survey will be depersonalised as soon as the survey is completed, which means that the person in your household who is interviewed, as well as your household, will not be identifiable in any report that is prepared. Research New Zealand is bound by the Professional Code of Practice of the European Society for Marketing and Opinion Research Inc. (the largest professional organisation of its type in the world), which prohibits us from identifying any person who takes part in a survey unless we have explicit consent from them to do so.
Do I have to take part in the survey?	No, your household doesn't have to do the survey. Participation in this survey is completely voluntary, but it is important that as many people as possible do so we can have a representative picture of the effects of noise in your neighbourhood.
When will the prizes be drawn?	The prize draw will happen in May 2017 when all surveying has been completed. The winners will be notified either by telephone or by email.
What if I want to find out more about it?	If you have any queries about the survey, please call Aaron McKay-Valentine (Project Manager, Research NZ) on Freephone: 0800 500 168 or email noise@researchnz.com